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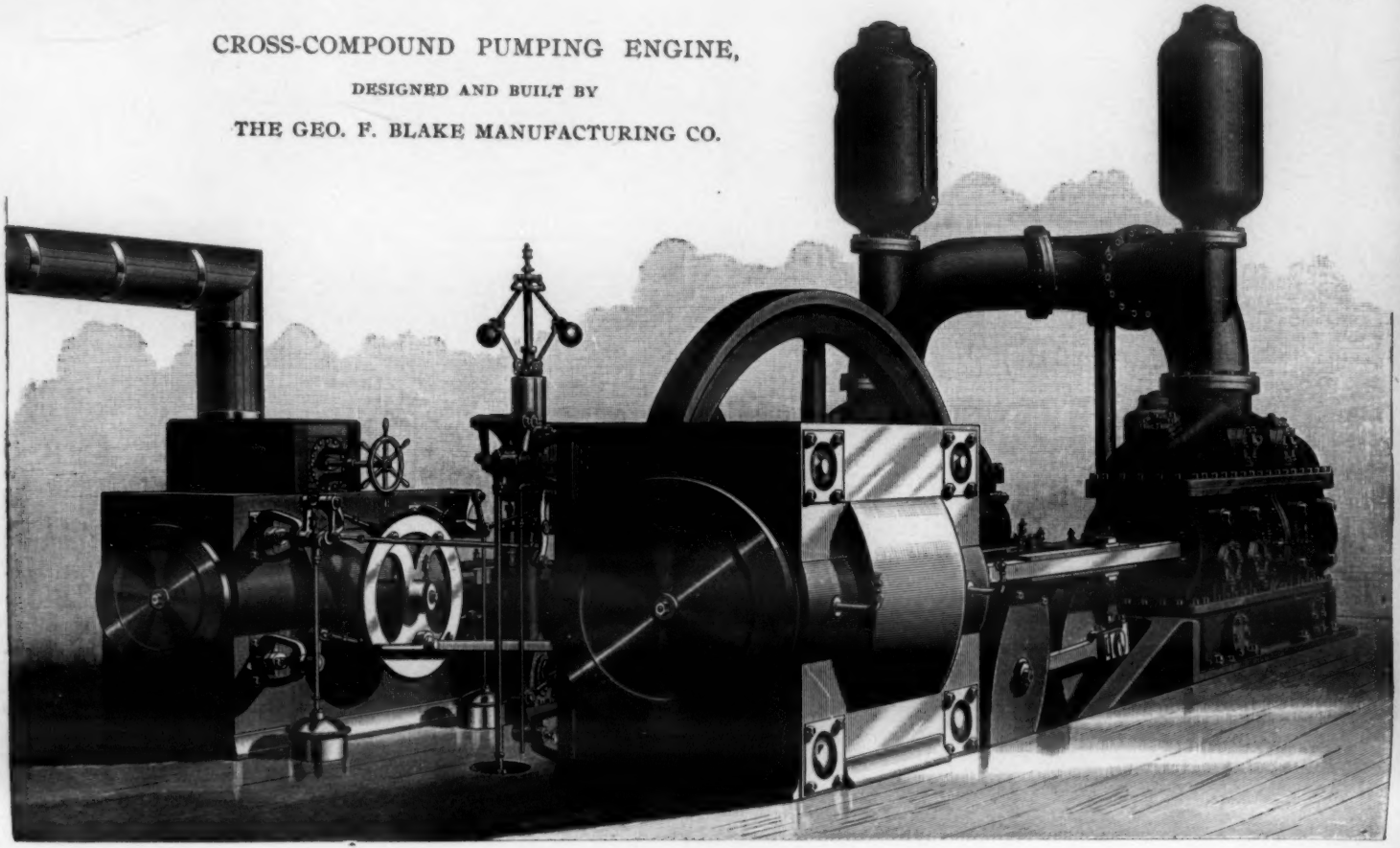

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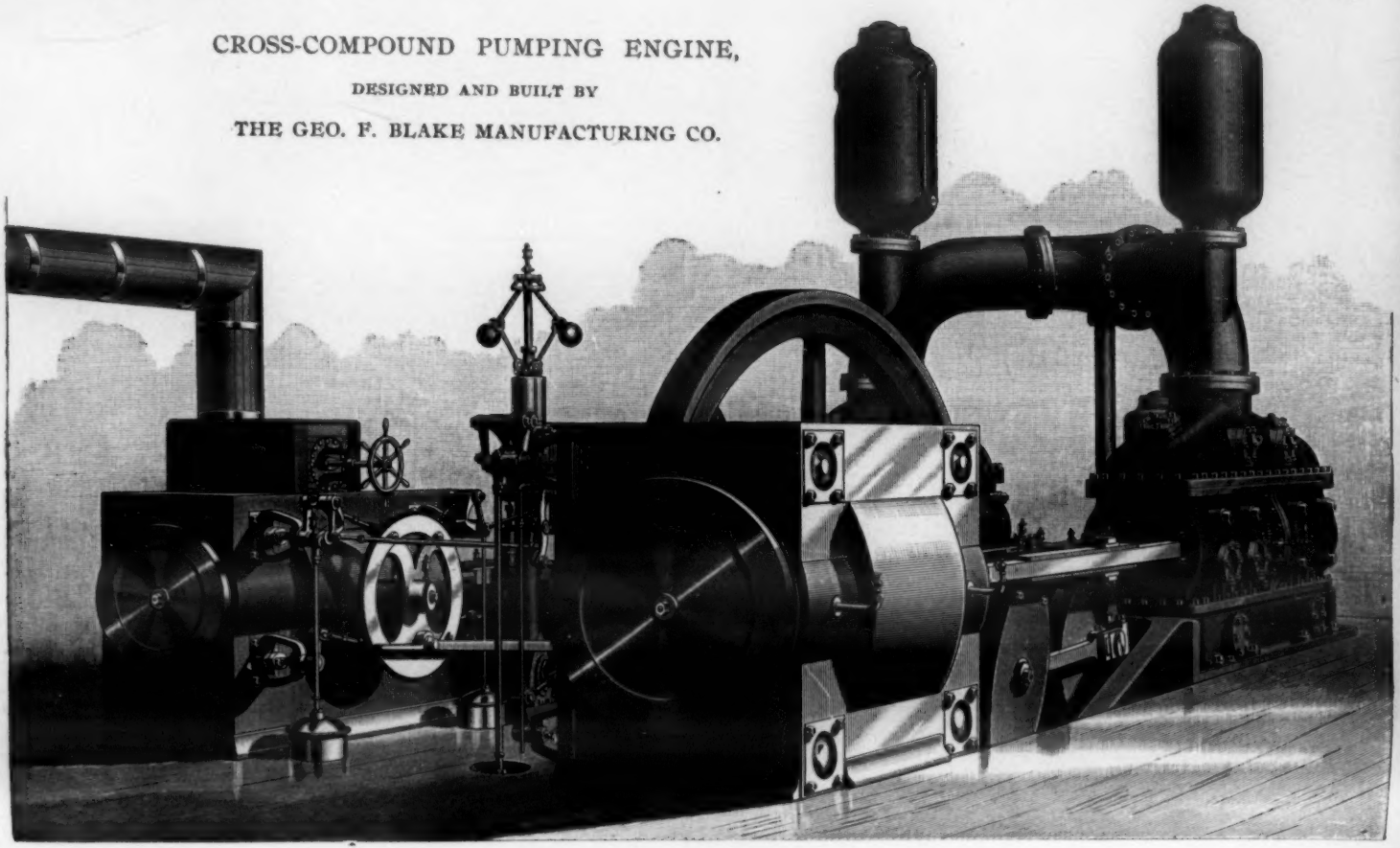
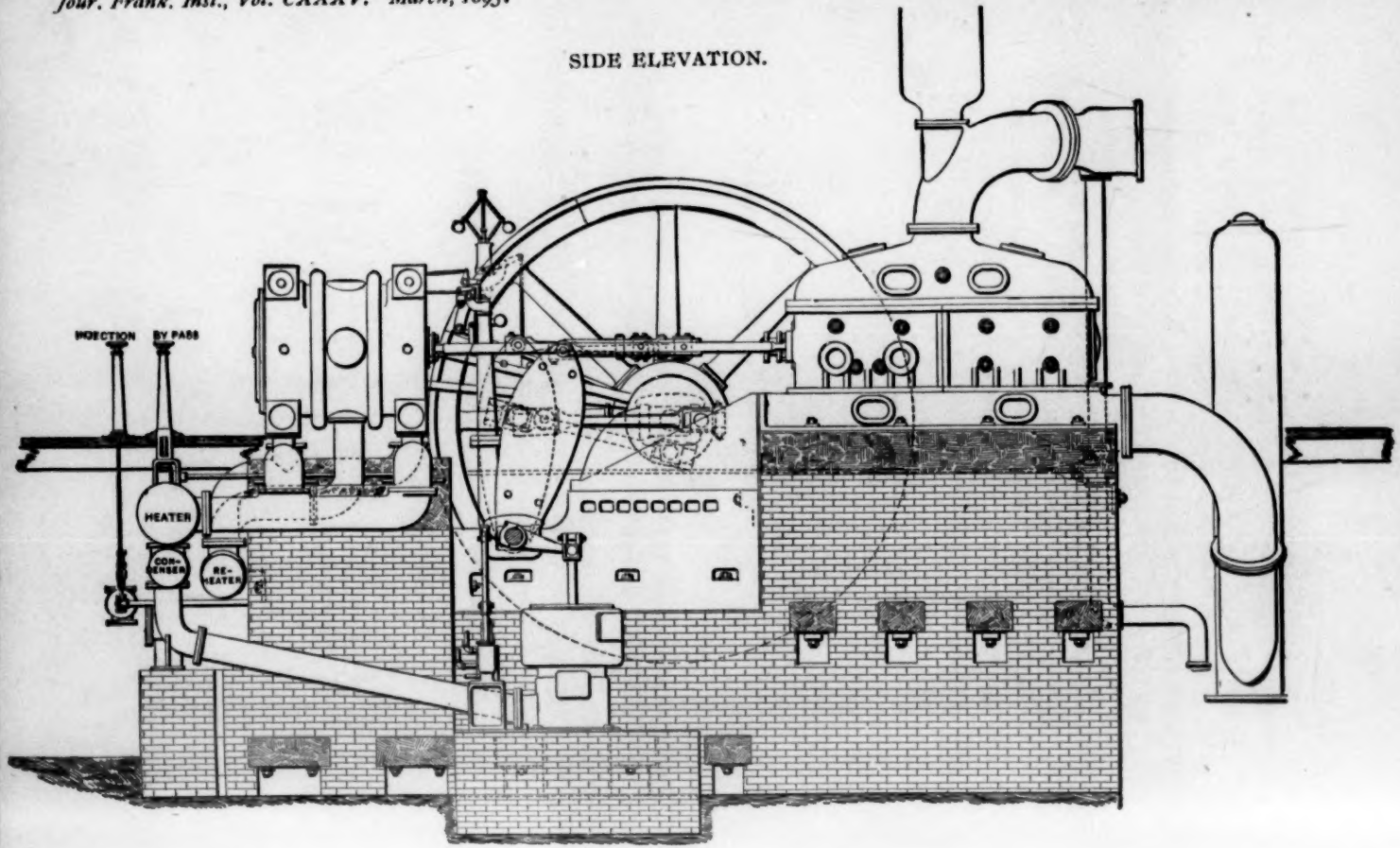


SIDE ELEVATION.



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DUTY TRIAL OF A PUMPING ENGINE, BUILT BY THE GEO. F. BLAKE MANUFACTURING COMPANY.

BY CECIL H. PEABODY, S.B.

In the spring of 1892, the author was requested by The Geo. F. Blake Manufacturing Company to make a duty trial of a pumping engine, designed and built by them for the City Water Works, of Newton, Mass., and located at Newton Upper Falls. The engine had then been running under the normal conditions of regular service for some time, and it, with the boilers, which however were furnished by the company, were in good regular running condition. The test was made solely for the information of the company, and the author considered it desirable that the conditions secured, and the precautions taken, should be such that the performance of the engine during the test

could be repeated at pleasure, with this engine or any engine of like size and type.

DESCRIPTION OF THE ENGINE.

The engine was built under the requirements that it should have sufficient capacity to deliver easily 5,000,000 U. S. gallons in twenty-four hours of continuous operation into the reservoir, through a force main 3½ miles long and 20 inches in diameter, against a maximum head, exclusive of friction in the pipes, of 235·25 feet. It should be mentioned, however, that the supply for the city is taken from this main at several points not far distant from the pumping station, by what is known as the direct indirect system.

The specifications required that the duty performed should be the number of pounds of water raised one foot high with a quantity of water evaporated into dry steam, the eqivalent of which shall be 1,100 pounds of water from and at 212° F. Based upon this unit of measurement the builders guaranteed a duty of 115,000,000 foot-pounds of work. It will be seen that the engine, during the test, showed a handsome excess over the guaranteed duty, and that the capacity as indicated by the plunger displacement was satisfactory.

The engine, which is shown in perspective and elevation by *Plates I* and *II*, may be described as of the direct-acting, fly-wheel, cross-compound type, having one high-pressure and one low-pressure steam cylinder with two double-acting inside plunger pumps. Both high and low-pressure cylinders are provided with valve gears of the Corliss type. The valves are closed by vacuum dash-pots with internal communications between the vacuum and cushion pressure, and the action of the gear is smooth and noiseless without clicking or hissing. The steam cylinders are jacketed on the barrels and on the heads, the jackets being cast with the cylinders. The steam for supplying both the cylinders and the high-pressure jacket is brought to the steam chest on top of the high-pressure cylinder: the jacket on that cylinder is in free

communication with the steam chest, and the condensation therein is drained away from the bottom of the jacket through a trap; during the test, this condensation was wasted and not allowed for. The loss from this cause, though small, must have been appreciable, and was, of course, against the performance of the engine.

The steam from the high-pressure cylinder exhaust space passed down into the intermediate receiver, which contained a tubular reheater presenting 120 square feet of heating surface, thence up through the low-pressure cylinder jacket and into the low-pressure steam chest. The reheater is supplied with steam under full boiler pressure, and the condensation is returned, under normal conditions, directly to the boiler by a special feed pump driven by the main engine; during the test this return was interrupted, and the steam from the reheater was measured and allowed for. The regular feed water for the boiler is drawn from the hot well and passed through a tubular exhaust steam feed water heater by a feed pump driven by the main engine.

DIMENSIONS OF THE ENGINE.

	Inches.
Diameter of the high-pressure cylinder,	21
Diameter of the low-pressure cylinder,	42
Diameter of two pump plungers,	13½
Diameter of all piston rods,	4
Stroke of all pistons and plungers,	40
Diameter of one single acting air pump,	26
Stroke of same,	12
Diameter of single-acting plunger feed pump,	4½
Stroke of same,	6
Diameter of pump plunger for returning reheater drain to boiler,	2
Stroke of same,	6

The diameters of the pump plungers and of the piston rod were calipered and measured. Other dimensions were supplied by the builders.

METHOD OF MAKING THE TRIAL.

The object of this test was to determine the steam and heat consumption of the engine, the power generated in the steam cylinders and exerted by the pump plungers, and the evaporative efficiency of the boiler supplying steam to the

engine, and therefrom to find the duty of the engine. No attempt was made to determine the quantity of water pumped, or the slip of the pump. For a boiler test not longer than twelve hours, it was deemed essential that a new fire should be built at the beginning of the test, and that the fire should be drawn at the end of the test; consequently the engine test was, from necessity, begun after the boiler test was started, and it was stopped before the boiler test was ended. It will be shown later how the results of the two tests, which were carried on at the same time, can be united so as to give the duty of the engine based on coal consumption.

The engine and boiler were run for some time under the normal conditions, at full power, before beginning the tests; when all was ready, the engine was run slowly, the fires in the boiler were drawn, and new fires were made with weighed wood and coal; when the fires were well alight, the boiler test was considered to be started. Half an hour after the boiler test was started, the test on the engine was begun; the engine itself was working at full power soon after the time taken for the beginning of the boiler test. The engine test continued for ten hours, but the engine ran at full power up to half an hour of stopping the boiler test, and continued to run nearly at full power till the fires were drawn.

The quantities determined are: the weight of coal (including equivalent of wood for kindling the fires); the weight and temperature of the feed water supplied to the boiler; the speed of the engine; the weight and quality of the steam used by the engine, both in the cylinders and in the reheater between the cylinders; the steam pressure at the boiler, and near the throttle valve of the engine; the weight and temperature of the water drained from the reheater; the power of the steam cylinders and of the pump plungers.

The coal was weighed in an iron barrow, and fired therefrom as required; no coal was allowed on the fire-room floor, which was swept clean. The feed water supplied to the boiler was weighed in a barrel on the engine-room floor,

and delivered to a large barrel in the basement, from which the feed pump connected to the engine was supplied during the test. The connection between the feed pump and the hot well was broken before the test began. The barrel in the basement was accurately filled to the same marked height at the beginning and end of the test; a valve in the pipe leading from this barrel to the feed pump was closed at the time of beginning and ending the boiler test, to facilitate this operation. The water level in the boiler, at the beginning of the boiler test, was marked on a wooden scale secured to the water glass on the boiler, and at the end of the test the water level was brought to the same mark. The boiler was making steam at about the same rate at the beginning and end of the test, and, moreover, the boiler made steam so freely and had so large a free water surface, that the apparent level of the water did not change with the rate of evaporation.

The speed of the engine was determined from the engine counter. The boiler undergoing test, supplied steam to the engine only; consequently the total steam supplied to the cylinders and the reheater was determined from the feed water supplied to the boiler during the time of the test on the engine. The level of the water in the barrel in the basement, from which the feed pump drew, was determined and marked at the beginning of the engine test; and in like manner the level in that barrel was determined and marked at the end of the test; the difference between the quantities of water in that barrel at the beginning and end of the engine test was subsequently determined and allowed for. The level of the water in the boiler at the beginning of the engine test was marked on the aforementioned scale attached to the water glass, and the level was brought to the same mark at the end of the engine test. The drain from the reheater, which is ordinarily returned directly to the boiler, was collected and weighed in a barrel, which had been partly filled with cold water to prevent vaporization and loss. When it became necessary to empty this weighing barrel and provide a new supply of cold water, the drain from the reheater was wasted; but these

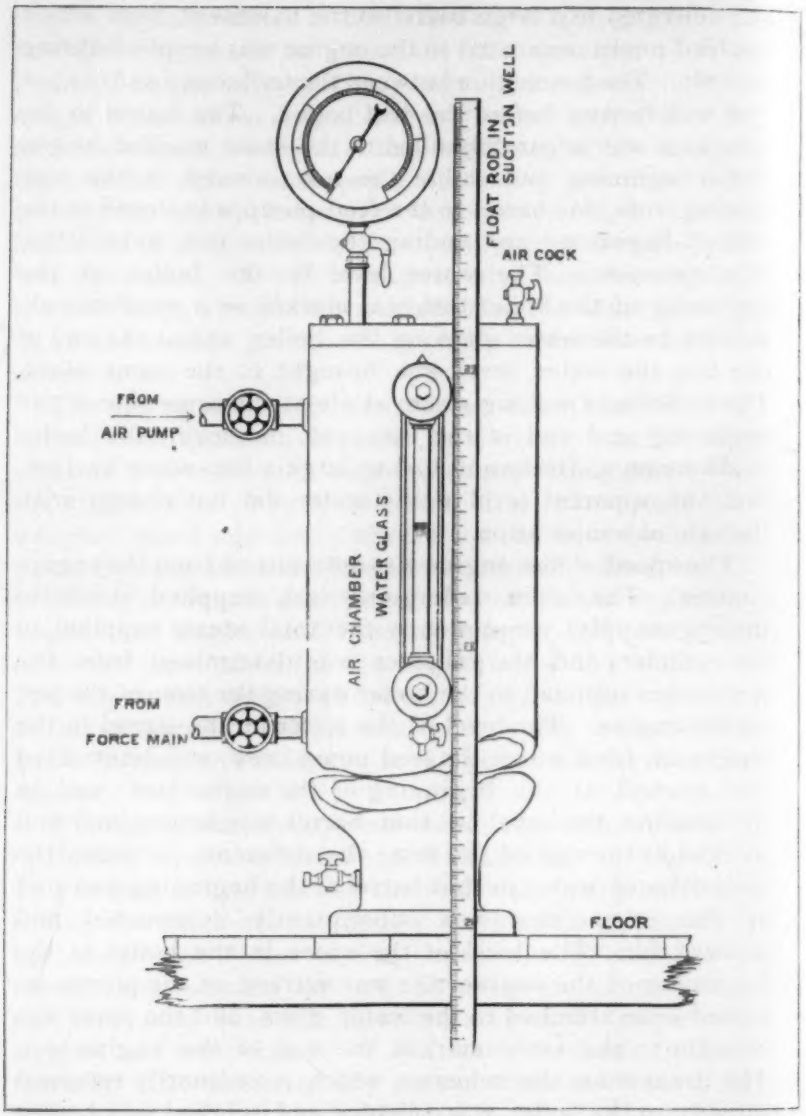


FIG. 1.

times were recorded and allowed for, from the rate of condensation determined from the time when the drain was caught and weighed. The temperature of the water drained

from the reheater was taken near the weighing barrel. A previous test (made April 27th) showed a loss of temperature between the barrel and the boiler of 38° F.; the same loss of temperature was assumed for this test.

The quality of the steam supplied to the engine was determined by a calorimeter near the throttle valve. The steam used by the calorimeter was gauged by causing it to flow through an orifice and was allowed for. The steam supplied to the reheater was assumed to have the same quality. The steam in the steam pipe near the boiler was assumed to be dry and saturated.

The pressure at the boiler, near the throttle valve, that in the calorimeter (when in use) and the vacuum were taken by the aid of test gauges. The steam supplied to the reheater was assumed to be under boiler pressure. Readings were taken every fifteen minutes. The pressure of the atmosphere was determined by a mercurial barometer.

The power of the steam cylinders was determined by the aid of indicator diagrams taken every fifteen minutes, all of which were reduced by the aid of planimeters. The power of the pump plungers was determined from the total water column against which the pump worked, not allowing in any way for the friction of foot valve, pump valves or suction main. To determine this water column, use was made of a device shown by *Fig. 1.*

The lower part of the chamber is placed in communication with the forcing main, and the upper part is filled with air; a glass gauge on the side shows the level of the water, and a gauge on the top of the chamber, which is not affected by troublesome jarring or fluctuation of its needle, gives the pressure of the air. The quantity of air in the chamber and the level of the water can be adjusted by aid of an air force pump. A float in the well carries a graduated rod which moves freely near the glass water gauge and allows the depth of the water in the well below the water line in the chamber to be read directly. The mean effective pres sure, under which the plungers worked, was taken to be the pressure equivalent of the water column, from the level of

the well to the level in the closed chamber, plus the pressure shown by the gauge on the top of this chamber.

All the instruments used during the tests, namely, the scales, indicators, gauges and thermometers, were tested and corrections were applied when necessary. All the apparatus was watched personally by the author, and readings were checked from time to time, and are known to be substantially correct.

OBSERVATIONS, WEIGHTS AND MEASUREMENTS.

The following tables give observations, weights and measurements, taken during the test, together with corrections:

ENGINE RECORD.—(*Date, April 30, 1892.*)

Time.		Counter.		Pressure by Gauge, in Pounds where not otherwise Stated.					Temperature Centigrade.	
H.	M.	Reading.	Diff.	On Boiler.	At Throttle	Vacuum in Inches.	Force Main.	Float Rod in Feet.	Reheater Drain.	Main Feed at Boiler.
10	00	22,191		127·5	124·0	27·2	110	18·54	161·0	46·0
	10		568				109	18·64		
	15	22,759		12,·5	123·0	27·0			162·3	46·0
	20		568				109	18·71		
	30	23,327		123·7	122·0	27·0	110	18·80	160·8	46·0
	40		566				110	18·87		
	45	23,893		125·9	123·0	27·0			160·0	46·0
	50		564				108	18·94		
11	00	24,457		124·0	121·5	27·0	109	19·02	159·7	46·2
	10		564				108	19·10		
	15	2·,021		124·0	121·0	27·1			160·5	47·0
	20		564				109	19·18		
	30	25,585		124·9	123·0	27·0	109	19·26	161·4	47·1
	40		565				110	19·35		
	45	26,150		125·1	121·5	27·0			160·8	47·0
	50		565				108	19·42		
12	00	26,715		123·9	122·5	27·2	109	19·49	160·8	47·0
	10		564				108	19·67		
	15	27,279		123·1	122·5	27·0			160·8	47·1
	20		564				109	19·74		
	30	27,843		124·0	120·5	27·2	110	19·82	160·6	46·0
	40		563				110	19·70		
	45	28,406		124·7	124·0	27·2			160·3	46·0
	50		565				108	19·75		
1	00	28,971		124·7	124·0	27·1	110	19·84	160·0	45·5
	10		565				110	19·92		
	15	29,536		124·0	122·0	27·1			160·1	47·0
	20		564				110	19·97		
	30	30,100		125·0	121·5	27·1	110	20·05	160·4	47·0
	40		564				111	20·17		
	45	30,664		125·1	121·5	27·1				47·1
	50		564							
2	00	31,228		124·5	124·0	27·0	109	20·25	160·8	46·3
	10		565				108	20·33		
	15	31,793		124·6	122·0	27·2			161·3	46·5
	20		565				110	20·40		
	30	32,358		123·0	121·5	26·9	111	20·46	161·0	47·5
	40		565				109	20·53		
	45	32,923		123·0	122·5	27·0			161·2	46·5
	50		564				108	20·47		

ENGINE RECORD —*Continued.*

Time.		Counter.		Pressure by Gauge, in Pounds where not otherwise Stated.					Temperature Centigrade.	
H.	M.	Reading.	Diff.	On Boiler.	At Throttle	Vacuum in Inches.	Force Main.	Float Rod in Feet.	Reheater Drain.	Main Feed at Boiler.
3	00	33,487		124·5	123·0	27·1	107	20·44	162·0	47·1
	10		565				108	20·48		
	15	34,052		123·0	120·5	27·2			161·7	46·8
	20		565				109	20·48		
	30	34,617		123·5	121·5	27·2	109	20·51	161·9	46·8
	40		565				110	20·57		
	45	35,182		124·1	123·0	27·3			161·8	46·1
	50		567				109	20·65		
4	00	35,749		124·3	123·5	27·1	108	20·70	162·1	47·0
	10		566				108	20·70		
	15	36,315		123·4	122·5	27·2			162·2	46·7
	20		567				107	20·60		
	30	36,882		125·1	124·0	27·4	106	20·65	162·3	47·0
	40		568				108	20·65		
	45	37,450		125·1	123·0	27·4			162·8	46·9
	50		566				105	20·70		
5	00	38,016		125·3	124·5	27·2	109	20·75	163·0	45·5
	10		567				109	20·80		
	15	38,583		125·5	124·0	27·3			162·3	45·0
	20		567				112	20·83		
	30	39,150		125·5	123·5	27·3	109	20·88	163·0	45·5
	40		565				107	20·91		
	45	39,715		126·5	123·0	27·1			162·5	46·1
	50		566				107	20·94		
6	00	40,281		123·1	121·0	27·3	112	20·97	162·8	45·6
	10		566				107	21·00		
	15	40,847		123·0	123·0	27·2			162·2	45·5
	20		566				108	21·05		
	30	41,413		129·0	124·5	27·3	107	21·08	163·5	45·5
	40		565				107	21·09		
	45	41,978		125·7	124·5	27·0			162·5	50·0
	50		566				106	21·13		
7	00	42,544		123·2	123·0	27·3	107	21·17	162·5	48·0
	10		566				107	21·22		
	15	43,110		123·3	121·5	27·4			162·0	48·0
	20		565				107	21·24		
	30	43,675		124·5	122·5	27·5	108	21·07	162·3	47·1
	40		566				107	21·11		
	45	44,241		124·0	124·0	27·4			162·2	47·0
	50		567				107	21·14		
8	00	44,808		125·5	123·5	27·4	106	21·14	161·0	47·0
Totals, ...		22,617		5111·3	5031·0	1114·	6512·	1214·64	6462·4	1911·
Means, ...				124·66	122·7	27·17	108·53	20·244	161·56	46·6
Corrected reading, ...				122·66	119·9	27·07	107·73	8·77 lbs.	161·52	46·6
Pressure of atmosphere, . .				14·8	14·8				322°·7 F.	116° F.
Absolute pressures, ...				137·46	134·7	Pressure on pump, 107·73 + 8·77 = 116·5 lbs.				

INDICATOR DIAGRAMS OF HIGH-PRESSURE STEAM CYLINDER—SCALE 100.

Card.	Head End.		Crank End.		Cut-off in Per Cent.	
	Area.	Length.	Area.	Length.	Head End.	Crank End.
1	1·84	4·57	2·38	4·58	17·5	23·
2	1·85	4·57	2·35	4·58	18·	23·
3	2·03	4·57	2·30	4·58	20·	22·5
4	2·07	4·58	2·12	4·58	20·	19·
5	2·15	4·58	2·13	4·59	22·5	20·
6	1·98	4·57	2·03	4·58	19·	18·
7	2·13	4·57	2·13	4·59	20·	19·5
8	2·09	4·57	2·11	4·58	21·	19·
9	2·04	4·57	2·02	4·59	20·5	19·5
10	2·10	4·57	2·04	4·58	22·5	19·
11	1·96	4·57	2·14	4·58	19·5	20·
12	2·04	4·57	2·11	4·59	20·	20·
13	2·20	4·57	2·14	4·59	22·5	20·
14	2·15	4·57	2·11	4·59	22·5	20·
15	1·98	4·57	2·02	4·59	19·5	18·
16	2·12	4·59	2·10	4·58	21·	19·
17	1·98	4·57	2·11	4·58	19·5	20·
18	2·09	4·57	2·09	4·59	20·5	19·
19	2·01	4·58	2·09	4·59	20·	19·5
20	2·18	4·57	2·13	4·58	23·	20·
21	1·98	4·58	2·14	4·59	19·	19·5
22	2·26	4·57	2·04	4·60	24·	19·5
23	1·96	4·57	2·06	4·58	19·	20·
24	1·94	4·57	2·02	4·58	19·	19·5
25	1·98	4·57	2·04	4·58	19·	19·
26	2·14	4·58	2·03	4·59	21·	19·5
27	2·16	4·58	2·00	4·59	21·	18·
28	1·97	4·59	2·10	4·58	19·	19·
29	2·04	4·59	2·04	4·59	20·	18·5
30	2·02	4·58	2·11	4·59	19·	18·5
31	2·08	4·57	2·11	4·59	21·	19·
32	2·23	4·57	2·12	4·59	22·	19·
33	2·08	4·57	2·07	4·59	20·	19·
34	2·09	4·59	2·17	4·59	20·5	20·
35	2·13	4·57	2·07	4·59	19·	18·
36	2·11	4·57	2·07	4·60	20·5	19·
37	2·07	4·59	2·07	4·59	20·	19·
38	1·98	4·59	2·05	4·59	20·	20·
39	2 18	4·58	2·06	4·59	21·5	19·
40	2·06	4·59	2·12	4·59	19·5	19·5
41	2·17	4·60	2·11	4·59	20·	18·5
Total, . .	84·62	187·62	86·25	188·06	833·0	799·0
Means, .	2·063	4·57	2·10	4·58	20·3	19.5

INDICATOR DIAGRAMS OF LOW-PRESSURE CYLINDER—SCALE 16.

Card.	Head End.		Crank End.		Cut-off in per Cent.	
	Area.	Length.	Area.	Length.	Head End.	Crank End.
1	3·50	4·59	3·73	4·62	23°	23·5
2	3·56	4·59	3·90	4·62	24°	24°
3	3·63	4·60	3·86	4·62	25°	24·5
4	3·63	4·60	3·75	4·62	27°	26°
5	3·60	4·60	3·74	4·62	27°	26°
6	3·65	4·60	3·76	4·62	27°	26°
7	3·56	4·60	3·81	4·63	24°	25°
8	3·58	4·60	3·79	4·62	25°	25°
9	3·58	4·60	3·88	4·62	24·5	25·5
10	3·77	4·61	3·82	4·62	26·5	25°
11	3·77	4·60	3·88	4·62	26·5	25°
12	3·70	4·61	3·92	4·63	25·5	26·5
13	3·70	4·61	3·86	4·62	26°	25°
14	3·79	4·60	3·86	4·61	26°	25°
15	3·73	4·60	3·88	4·62	26·5	25°
16	3·65	4·61	3·86	4·62	25·5	25°
17	3·72	4·61	3·79	4·63	26°	23°
18	3·62	4·61	3·83	4·62	26°	25°
19	3·71	4·62	3·87	4·62	26°	25°
20	3·58	4·60	3·88	4·62	26°	26°
21	3·56	4·61	3·78	4·62	24°	24°
22	3·56	4·60	3·85	4·62	24·5	26°
23	3·61	4·60	3·81	4·62	25·5	24°
24	3·83	4·60	3·74	4·62	26·5	24°
25	3·67	4·61	3·84	4·61	25·5	24°
26	3·75	4·60	3·88	4·61	26·5	25°
27	3·68	4·60	3·93	4·61	24°	26°
28	3·61	4·61	3·81	4·61	23·5	25°
29	3·72	4·61	3·77	4·62	25·5	23·5
30	3·50	4·60	3·75	4·62	27·5	24·5
31	3·57	4·60	3·85	4·61	24·5	24·5
32	3·49	4·59	3·82	4·62	23°	24°
33	3·57	4·59	3·74	4·61	24°	24°
34	3·74	4·60	3·75	4·62	26°	24°
35	3·53	4·60	3·82	4·62	22·5	25°
36	3·60	4·61	3·80	4·62	25°	25·5
37	3·80	4·62	3·69	4·59	25·5	24·5
38	3·58	4·60	3·74	4·62	25·5	24·5
39	3·67	4·61	3·72	4·62	24°	23·5
40	3·62	4·60	3·76	4·62	25°	24·5
41	3·44	4·60	3·75	4·62	23°	24·5
Totals, .	149·14	188·72	156·27	189·35	1034·0	1015·5
Means, .	3·64	4·60	3·81	4·61	25·2	24·8

COAL AND BOILER RECORD.

Time of Firing.	*Wood and Coal. Barrow Full.*		*Barrow Empty.*	*Weight of Coal or Wood.*		*Gauge Pressure on Boiler.*	*Temp. of Feed at Boiler. Cent.*
9·26	356 lbs.	wood.	141·5	214·5	wood.		
	398·5 lbs.		141·5	257·0			
	471·5 × 0·4 = coal equivalent of wood = 188·6 lbs.						
9·30	636·5	coal.	236·5	400		130·5	
40							
45	636·5		236·5	400		126·7	48·0
10·00	engine test commenced.					127·5	46·0
15						129·5	46·0
30						123·7	46·0
40							
45	636·5		236·5	400		125·9	46·0
11·00						124·0	46·2
15						124·0	47·0
30						124·9	47·1
35							
45						125·1	47·0
12·00						123·9	47·0
15	636·5		236·5	400		123·1	47·1
20							
30						124·0	46·0
35							
45						124·7	46·0
1·00	636·5		236·5	400		124·7	45·5
15						124·0	47·0
30						125·0	47·0
45						125·1	47·1
2·00	636·5		236·5	400		124·5	46·3
15						124·6	46·5
30						123·0	47·5
45						123·0	46·5
3·00	636·5		236·5	400		124·5	47·1
05							
15						123·0	46·8
30						123·5	46·8
45	636·5		236·5	400		124·1	46·1
4·00						124·3	47·0
4·15						123·4	46·7
30						125·1	47·0
45	636·5		236·5	400		125·1	46·9
5·00						125·3	45·5
10							

COAL AND BOILER RECORD.—(*Continued.*)

Time of Firing.	Wood and Coal, Barrow Full.	Barrow Empty.	Weight of Coal or Wood.	Gauge Pressure on Boiler.	Temp. of Feed at Boiler. Cent.
15				125·5	45·0
30				125·5	45·5
40					
45				126·5	46·1
6·00	636·5	236·5	400	123·1	45·6
15				123·0	45·5
30				129·0	45·5
45				125·7	50·0
50					
7·00				123·2	48·0
10	636·5	236·5	400		
15				123·3	48·0
30				124·5	47·1
45				124·0	47·0
8·00	engine test ended.			125·5	47·0
15	pump not feeding.			121·0	
30				126·3	49·0
35	636·5	476·0	160·5		
45				123·0	47·0
9·15	stopped.			129·8	
Totals,			4749·1	5868·6	2055·0
Means,				124·87	46·7
			error	2·	
Drawn from grate,	437·5	236·5	201·0	122·87	116·°06F.
Drawn from ash pit,	318·	141·5	176·5	14·8	
			absolute	137·67	

Sample of coal and ashes from grate, ... 8¼ oz. of ash.
5¾ oz. of coal.
14 oz. total.

Sample of coal and ashes from ash pit, ... 6⅝ oz. of ash.
1⅜ oz. of coal.
8 oz. total.

Unburnt coal in ash pit, ... $\frac{11}{64} \times 176{\cdot}5 = 30{\cdot}3$ pounds.
Unburnt coal left on grate, ... $= \frac{33}{80} \times 201 = 82{\cdot}5$ pounds.

Unburnt coal left on grate and in pit, ... = 112·8 pounds.

Ash and cinders in ash pit. . . . . $= \frac{33}{61} \times 176{\cdot}5 = 146{\cdot}2$ pounds.
Ash and cinders left on grate, . . . $= \frac{33}{80} \times 201 = 118{\cdot}5$ pounds.

Total refuse of ash and cinders, ... 264·7 pounds.

Per cent. of ash in coal $= \frac{264{\cdot}7}{100\ (4749{\cdot}1 - 112{\cdot}8)} = 5{\cdot}7$ per cent.

Coal burned, ... 4749·1 — 201 = 4548·1 pounds.

FEED-WATER RECORD.

Total feed water for boiler test, ... 44704·5 pounds.
Total feed water for engine test, ... 38501·5 pounds.

RECORD OF REHEATER DIAMETER.

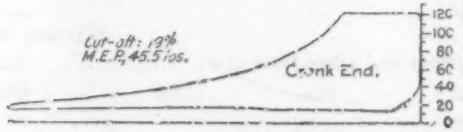
Time.	Weight in Pounds, of Barrel, at Beginning.	Weight and Barrel at the End.	Difference or Water Drained.
10·00	1,286		
11·15	*	1,711	425
·25	1,204		
12·30	*	1,592	388
·45	1,202		
1·45	*	1,566	364
2·00	1,206		
3·00	*	1,567	361
3·15	1,109		
4·30	*	1,560	451
4·45	1,104		
6·00	*	1,553	449
6·15	1,106		
7·45	*	1,649	543

For 8 hours 20 minutes, ... 2,981 pounds.
For 10 hours, ... 3,577·2 pounds.

* Water ran to waste during emptying of barrel, for 1 hour 40 minutes.

One set of indicator diagrams, taken at 2·15 and numbered 18 in the table of areas and lengths of the diagrams,

FIG. 2.



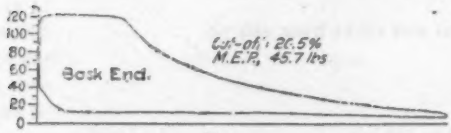


FIG. 3.

is shown by *Figs. 2, 3, 4* and *5*. It will be noticed that the areas and lengths are very nearly the same as the corres-

ponding averages for the entire test; further, it should be stated, that they are fair average samples.

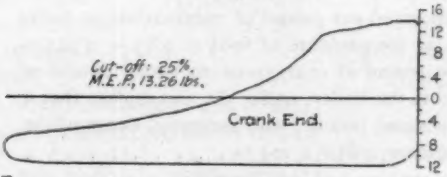
HIGH-PRESSURE CYLINDER, CRANK END.

Area	2·09 sq. in.
Length,	4·59 in.
M.E.P.,	45·5 lbs.
Cut-off,	19 per cent.

HIGH PRESSURE CYLINDER, BACK END.

Area,	2·09 sq. in.
Length,	4·57 in.
M.E.P.,	45·7 lbs.
Cut-off,	20·5 per cent.

FIG. 4.



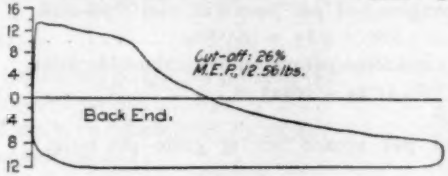


FIG. 5.

LOW-PRESSURE CYLINDER, CRANK END.

Area,	3·83 sq. in.
Length,	4·62 in.
M.E.P.,	13·26 lbs.
Cut-off,	25 per cent.

LOW-PRESSURE CYLINDER, BACK END.

Area,	3·62 sq. in.
Length,	4.61 in.
M.E.P.,	12·56 lbs.
Cut-off,	26 per cent.

DATA AND CALCULATIONS.

Boiler Test.

Duration of test, 11 hours 45 minutes, or	11·75 hours.
Average pressure, by gauge,	122·87 pounds.
Atmospheric pressure,	14·8 pounds.

Average absolute pressure,	137·67 pounds.
Average temperature of feed,	116°·06 F.
Total heat above 32° F., of steam of 137·67 pounds per sq. inch,	*1189·1
Heat in water of temperature of 116°·06 F., above 32° F.	84·1
Heat given to every pound of water fed to the boiler, under the assumption that it was evaporated into dry and saturated steam of the boiler pressure, 1189·1 — 84·1 =	1105·0 B.T.U.
Total water fed to the boiler,	44704·5 pounds.
Total coal consumed,	4548·1 pounds.
Water evaporated per pound of coal at boiler pressure and temperature of feed, 44704·5 ÷ 4548·1 =	9·83 pounds.
Ash per pound of coal,	0·057 pound.
Combustible per pound of coal,	0·943 pound.
Water evaporated per pound of combustible at boiler pressure at temperature of feed = 9·83 ÷ 0·943 =	10·42 pounds.
B.T.U., per pound of coal, given to every pound of water fed to the boiler, under the assumption that it was evaporated into dry and saturated steam of the boiler pressure, 9·83 × 1,105 =	10862·15
Equivalent evaporation per pound of coal from and at 212° F. = 1,105 × 9·83 ÷ 965·8 =	11·25 pounds.
Equivalent evaporation per pound of combustible from and at 212° F., 11·25 ÷ 0·943 =	11·93 pounds.
Area of grate,	48·125 feet.
Coal burned per square foot of grate per hour, $= \frac{4548 \cdot 1}{11 \cdot 75 \times 48 \cdot 125}$	8·04 pounds.

Atmospheric Pressure (*Green's Mercurial Barometer*).

Barometer at 10·30 A. M.,	30″·20,	temp. 71° F.
at 3·00 P. M.,	30″·25,	temp. 74° F.
mean,	30″·225,	temp. 72° F.

Reauction to freezing point.†

$$\text{Height} = \frac{[1 + s(t - 62)] \times h}{1 + m(t - 32)}$$

where

h = reading of the barometer;
t = temperature of the attached thermometer;
m = expansion of mercury for 1° F., taken as 0·0001010 of its length at 32° F.;

* This and other properties of saturated steam are taken from the author's *Tables of the Properties of Saturated Steam.* J. Wiley & Son.

† See *Instructions for Voluntary Observers*, United States Department of Agriculture, p. 39, Washington, 1892.

s = expansion of the substance of which the scale is made; for brass s is taken as 0·00001020 of its length (h) at the standard temperature for the scale, viz: 62° F.

Substituting the above values in this formula, we have

$$\text{reduced height} = \frac{30{\cdot}225\ [\,1 + 0{\cdot}00001020\ (72 - 62)\,]}{1 + 0{\cdot}0001010\ (72 - 32)} = 30{\cdot}1$$

The weight of one cubic inch of mercury of the temperature of 32° F. is 0·491 pounds, and consequently the pressure of the atmosphere in this case will be

$$30{\cdot}1 \times 0{\cdot}491 = 14{\cdot}8 \text{ pounds.}$$

Calorimetric Test.

Mean gauge pressure for flow of steam, ...	119·9 pounds.
Pressure of atmosphere, ...	14·8 pounds.
Absolute steam pressure, ...	134·7 pounds.
Diameter of orifice, ...	0·2 inch.
Area of orifice, ...	0·031415 sq. inch.
Total time in which calorimeter was in use, . . .	75 minutes.

Weight of steam through calorimeter is then

$$\frac{75 \times 60 \times 134{\cdot}7 \times 0{\cdot}031415}{70} = 272 \text{ pounds.}$$

Pressure of steam, by gauge, for priming test, . . .	117·9 pounds.
Absolute pressure for do., ...	132·7 pounds.
Pressure of steam in calorimeter, by gauge, ...	11·8 pounds.
Absolute pressure in do., ...	26·6 pounds.
t_n temperature of steam in calorimeter, ...	298°·4 F.
r for pressure 132·7 pounds, ...	868·3 B.T.U.
q for pressure 132·7 pounds, ...	320·0 B.T.U.
λ_n for pressure 26·6 pounds, ...	1156·2 B.T.U.
t_0 for pressure 26·6 pounds, ...	243·47
c_p	0·48

The weight of dry steam per pound of the mixture will then be

$$\frac{1156{\cdot}2 + 0{\cdot}48\ [298°{\cdot}4 - 243°{\cdot}47] - 320}{868{\cdot}3} = 0{\cdot}993 \text{ pounds.}$$

and the priming, ... $(1 - 0{\cdot}993)\ 100 = 0{\cdot}7$ per cent.

HORSE-POWERS AND WORK ON THE PUMP PLUNGERS.

Areas of Steam Pistons.

High pressure,	head end, ...	546·361 sq. in.
	crank end (rod 4″), ...	333·795 sq. in.
Low pressure,	head end, ...	1385·44 sq. in.
	crank end (rod 4″), ...	1372·874 sq. in.

Mean Effective Pressures.

High pressure, head end,	45·10 pounds.
crank end,	45·85 pounds.
Low pressure, head end,	12·65 pounds.
crank end,	13·20 pounds.
Revolutions in ten hours,	22,617

Horse-powers of Steam Cylinders.

High-pressure cylinder,

$$\frac{(346{\cdot}361 \times 45{\cdot}10 + 333{\cdot}795 \times 45{\cdot}85) \times 22{,}617 \times 40}{10 \times 60 \times 33{,}000 \times 12} = 117{\cdot}751$$

Low-pressure cylinder,

$$\frac{(1385{\cdot}44 \times 12{\cdot}65 + 1372{\cdot}87 \times 13{\cdot}20) \times 22{,}617 \times 40}{10 \times 60 \times 33{,}000 \times 12} = 135{\cdot}731$$

Total indicated horse-power of steam cylinders, ... 253·482

Work and Horse-power of Pump Plungers.

Area of $13\frac{1}{2}''$ circle,	143·139 sq. in.
One-half area of $4''$ circle,	6·283 sq. in.
Mean area of pump plunger,	136·856 sq. in.
Pressure per square inch, 8·77 + 107·73,	116·50 pounds.
Revolutions in ten hours,	22,617.

Work on Plungers for Ten Hours.

$$22{,}617 \times 116{\cdot}5 \times 136{\cdot}856 \times 4 \times \tfrac{12}{12} = 4{,}807{,}990{,}000 \text{ foot-pounds.}$$

Horse-power of pump plungers,

$$\frac{4{,}807{,}990{,}000}{10 \times 60 \times 33{,}000} = \ldots\ldots 242{\cdot}8$$

Efficiency of mechanism, ... $= \frac{242{\cdot}8}{253{\cdot}5} = 0{\cdot}958$

Friction of engine, ... 4·2 per cent.

Displacement of Pump Plungers for Twenty-four Hours.

Revolutions per minute, ... $= \frac{22{,}617}{600} = 37{\cdot}695$

$$\text{Displacement} = \frac{136{\cdot}856 \times 40 \times 4 \times 24 \times 60 \times 37{\cdot}695}{231} = 5{,}144{,}675 \text{ gallons.}$$

British Thermal Units (B.T.U.) used by the Engine, etc.

Temp. of feed at the boiler during the boiler test,	116°·06 F.
Temp. of feed at the boiler during engine test,	116°·00 F.
Average absolute steam pressure at the throttle during engine test,	134·7
Heat, r, of vaporization of steam of the above pressure (above 32° F.),	867·4 B.T.U.

Heat of the liquid q, corresponding to the pressure 134·7 absolute, above 32° F., ... 321·2 B.T.U.
Heat, q_0, of water of 116° F. above 32° F., ... 84 B.T.U.
Feed water supplied to boiler during engine test, . 38501·5 pounds.
Steam used by calorimeter, ... 272 pounds.
Steam used by engine in cylinders and reheater, . 38229·5 pounds.
Steam used in reheater, ... 3577·2 pounds.
Weight of mixture passing through steam cylinders, 34652·3 pounds.
Temp. of reheater return at the boiler, 323–38, = 285° F.
Average absolute steam pressure at the boiler during engine test, ... 137·46 pounds.
Heat, r_1, of vaporization of steam of the above pressure (above 32° F.) . . . . . = 866·2 B.T.U.
Heat, q_1, of liquid corresponding to the steam pressure of 137·46 pounds, absolute (above 32° F.) 322·9 B.T.U.
Heat, q_2, of water of 285° F. (above 32° F.), ... 245·4

The thermal units passing through the steam cylinders will then be

$34652{\cdot}3\ [0{\cdot}993 \times 867{\cdot}4 + 321{\cdot}2 - 84] =$ 38,065,550

The thermal units passing through the reheater will be

$3577{\cdot}2\ [0{\cdot}993 \times 866{\cdot}2 + 322{\cdot}9 - 254{\cdot}4] =$ 3,321,788
Total B.T.U. used during engine test, ... 41,387,338
B.T.U. used by engine per pound of coal $= 9{\cdot}83 \times 1{,}105 =$ 10,862

Duties.

Work on pump plungers for ten hours, . 4,807,990,000 foot-pounds.
Heat used by the engine in ten hours, ... 41,387,338 B.T.U.
Coal required by the engine in ten hours,

$$\frac{41{,}387{,}338}{10{,}862} = \text{. . . .} \quad 3{,}833 \text{ pounds.}$$

Mixture of steam and water used by the engine in ten hours, ... 38229·5 pounds.

The duties as expressed in the various ways used in practice, will then be

(1) Per 1,000,000 B.T.U.:

$$\frac{4{,}807{,}990{,}000 \times 1{,}000{,}000}{41{,}387{,}338} = 116{,}170{,}000 \text{ foot-pounds.}$$

(2) Per 1,062,380 B.T.U., or per 1,100 pounds of steam at 212° F., as per basis in Newton Specifications:

$$\frac{4{,}807{,}990{,}000 \times 1{,}062{,}380}{41{,}387{,}338} = 123{,}420{,}000 \text{ foot-pounds.}$$

(3) Per 100 pounds of coal:

Steam pressure at the boiler, absolute. . . . . 137·46 pounds.
B.T.U. per pound of steam (above 32° F.,) of this pressure, ... 1,189
Temperature of feed water at the boiler, ... 116° F.
Heat of liquid (above 32° F.), corresponding . . . 84 B.T.U.
Temperature of reheater drain at the boiler, ... 285° F.
Heat of liquid (above 32° F.), corresponding, ... 254·4 B.T.U.
B.T.U. supplied by boiler to steam delivered to the steam cylinders, $34652{\cdot}3 \times (1{,}189 - 84) = 34652{\cdot}3 \times 1{,}105 =$ 38,290,792
B.T.U. supplied by boiler to steam delivered to the reheater, $3577{\cdot}2 \times (1{,}189 - 2544 = 3577{\cdot}2 \times 934{\cdot}6 =$ 3,343,251
Total B.T.U. supplied by boiler to steam passing through cylinders and reheater, ... 41,634,043
Heat developed per pound of steam during the boiler test, ... 1,105 B.T.U.
B.T.U. per pound of coal, ... 10,862
Coal used in ten hours,

$$\frac{41{,}634{,}043}{10{,}862} = \ldots\ldots 3{,}833 \text{ pounds.}$$

Then the duty will be

$$\frac{4{,}807{,}990{,}000 \times 100}{3{,}833} = 125{,}400{,}000, \text{ foot-pounds.}$$

(4) Per 100 pounds of coal calculated upon the assumption that one pound of coal is required to evaporate every ten pounds of water fed to the boiler:

Water fed to boiler, ... 38229·5

$$\frac{4{,}807{,}990{,}000 \times 100}{3{,}824} = 125{,}762{,}490 \text{ foot-pounds.}$$

Economy of Engine.

Steam used in cylinders and reheater in ten hours, 38229·5 pounds.
Coal required by the engine for ten hours, . . . 3,833 pounds.
B.T.U. used by the engine in ten hours, ... 41,387,338
Steam per horse-power per hour,

$$\frac{38229{\cdot}5}{10 \times 253{\cdot}5} = \ldots\ldots 15{\cdot}08 \text{ pounds.}$$

Coal per horse-power per hour,

$$\frac{3{,}833}{10 \times 253{\cdot}5} = \ldots\ldots 1{\cdot}51 \text{ pounds}$$

B.T.U. per horse-power per minute,

$$\frac{41{,}387{,}338}{10 \times 60 \times 253{\cdot}5} = \ldots\ldots 272$$

At the time of the test no provision was made for taking the temperature of the feed water near the engine. Subsequent observations showed a loss of 13° F. between the engine and the boiler, when the engine was running under the same conditions. The probable temperature of the feed water during the test was 116° + 13° = 129° F.; the reheater drain near the engine had a temperature during the test of 322°·7 F. The duty of the engine, calculated from the heat supplied to the engine and rejected by the engine, may be stated as follows:

CALCULATIONS BASED UPON THE HEAT SUPPLIED TO AND RETURNED BY THE ENGINE.

Temperature of feed water at engine, ...	129° F.
Temperature of reheater drain at engine, ...	322°·7 F.
Heat of liquid of temperature 129° F. (above 32°), . . .	97°·1 F.
Heat of liquid of temperature 322°·7 F. (above 32°), . .	292°·8 F.

Substituting the above values in the formula already used, we have

B.T.U. per pound of steam passing through the steam cylinders, (0·993 × 867·4 + 321·2 — 97·1) = ...	1,085·4
B.T.U. per pound of steam passing through the reheater, (0·993 × 866·2 × 322·9 — 292°·8 F.) = ...	890·2

And the B.T.U. used by the engine,

In the steam cylinders, 34652·3 × 1085·4 = ...	37,611,607
In the reheater, 3577·2 × 890·2 = ...	3,184,423
Total B.T.U. used by the engine, ...	40,796,030

B.T.U. per horse-power of steam cylinders per minute,

$$\frac{40{,}796{,}030}{600 \times 253{\cdot}482} = \ldots\ldots\ldots \quad 268$$

B.T.U. per horse-power of pump cylinders per minute,

$$\frac{40{,}796{,}030}{600 \times 242{\cdot}8} = \ldots\ldots\ldots \quad 280$$

Duty per 1,000,000 B.T.U.,

$$\frac{4{,}807{,}990{,}000}{40{,}796{,}030} = \ldots\ldots 117{,}850{,}000 \text{ foot-pounds.}$$

Duty on the Newton basis,

$$\frac{4{,}807{,}990{,}000}{40{,}796{,}030} \times 1{,}062{,}380 = 125{,}200{,}000 \text{ foot-pounds.}$$

The results of the test, together with a few of the principal data, are assembled in the following table:

Boiler Test:	
Duration,	11 hours 45 minutes.
Temperature of feed water,	116·°06 F.
Pressure of steam by gauge,	122·87 pounds.
Pressure of the atmosphere,	14·8 pounds.
Water evaporated from temperature of feed water, into dry steam under boiler pressure, per pound of coal,	9·83 pounds.
Water evaporated (as above) per pound of combustible, allowing 5·7 per cent. ash,	10·42 pounds.
Equivalent evaporation from and at 212° F., per pound of coal,	11·25 pounds.
Equivalent evaporation from and at 212° F., per pound of combustible,	11·93 pounds.
Coal burned per square foot of grate per hour,	8·04 pounds.
Calorimeter Test:	
Priming, moisture in steam,	0·7 per cent.
Engine Test:	
Duration,	10 hours.
Average revolutions per minute,	37·695
Steam pressure at boiler by gauge,	122·66 pounds.
Steam pressure at throttle,	119·9 pounds.
Vacuum,	27·1 inches.
Pressure of the atmosphere,	14·8 pounds.
Cut-off high-pressure cylinder,	20 per cent
Cut-off low-pressure cylinder,	25 per cent.
Effective pressure exerted by plungers,	116·5 pounds.
Indicated horse-power, high-pressure cylinder,	117·75
Indicated horse-power, low-pressure cylinder,	135·73
Indicated horse-power of engine,	253·48
Steam per horse-power per hour,	15·08 pounds.
B.T.U., per horse-power per minute,	272
Coal per horse-power per hour,	1·51 pounds.
Horse-power of pump plungers,	242·8
Efficiency of mechanisms,	0·958
Friction,	4·2 per cent.
Duty on basis of 1,000,000 B.T.U.,	116,170,000
Duty on Newton basis,	123,420,000
Displacement of pump plungers for twenty-four hours, not allowing for slip,	5,144,675 gals.

The duty of the engine, in the assembled results, is given (1) on the basis of 1,000,000 B.T.U., which is recom-

mended by a committee of the American Society of Mechanical Engineers, and (2) on the basis prescribed by the specifications under which the engine was built, namely, the equivalent of 1,100 pounds of water from and at 212° F.

While it is believed that the numerous and varying standards of pump performance, all known as *duty*, are responsible for much disagreement and misunderstanding, it is thought that, for purposes of comparison, it is well to give the duty of this engine referred to two other standards in common use.

They are:

Duty on basis of 100 pounds of coal, . . 125,400,000 foot-pounds.
Duty on 100 pounds of coal, calculated on the assumption that one pound of coal is required to evaporate ten pounds of water fed to the boiler, . . 125,762,490 foot-pounds.

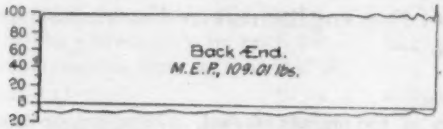
This last method is evidently entirely arbitrary and highly artificial; it appears to have the merit of giving a high record.

In comparing tests on different engines, the convenient, and probably the fairest way, is to use pressures and temperatures taken at or near the engine, thereby eliminating the question of the good or bad economy of the boiler and of the losses of pressure and temperature in the steam pipe and in the boiler feed pipe. A like strict interpretation of the performance of a boiler requires that the temperatures and pressures shall be taken at or near the boiler, and the application of both of these rules in practice would remove the responsibility of the losses due to the conveyance of steam and water alike from the engine and the boiler-maker and transfer it to the owner, where it may in some cases belong. The makers of this engine have thought best to disregard this small, though appreciable disadvantage, in order to give more nearly its commercial value. For purposes of comparison with other engines, the following results have been calculated from the heat supplied to and returned by the engine:

Duty per 1,000,000 B.T.U., ... 117,850,000 foot-pounds.
Duty on the Newton basis, ... 125,200,000 foot-pounds.

Though forming no part of the trial, and not used in reducing the results of the test, the indicator diagrams, shown by *Figs. 6* and *7*, and taken by Mr. Albert F. Hall, the Constructing Engineer of The George F. Blake Manufacturing Company, may be of interest. They were taken with a Thompson indicator on a short one-inch pipe, with a straight-way valve on the pipe and the indicator cock wide open. The engine at the time was making thirty-eight

FIG. 6.



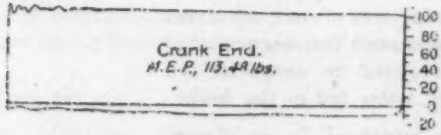


FIG. 7.

revolutions per minute, and was in general under very nearly the same conditions as at the time of the trial here reported.

BACK END.

Scale 100. JUNE 11, 1892, 10.40 A. M.

Area,	4·84 sq. in.
Length,	4·44 sq. in.
M.E.P.,	109·01 lbs.

CRANK END.

Scale 100. 11 A. M.

Area,	5·05 sq. in.
Length,	4·45 in.
M.E.P.,	113·48 lbs.

During the entire test the engine ran smoothly and regularly with the same attention that it would receive in good ordinary practice. The regularity of the steam pressure, the suction and the pressure on the pump, and of the work of the steam pistons is shown in the recorded results.

MANGANESE STEEL.

By Henry M. Howe.

[*A lecture delivered before the Franklin Institute, February 20, 1892.*]

[*Concluded from p. 128.*]

Speaking roughly, we may say that water toughening increases the ductility of manganese steel some fivefold, and occasionally even tenfold; while often at the same time doubling the tensile strength.

In *Fig. 9*, I attempt to show simultaneously how the strength and ductility of manganese steel both increase as we hasten the cooling of the metal; in other words, that the faster we cool it, the stronger and more ductile we find it. Each of the several lines here drawn gives the tensile strength (as abscissa), and the elongation (as ordinate) of pieces of manganese steel cooled at different rates, but in all other respects alike. The semi-circles with the letter N by them, as before, represent the metal in its natural or slowly cooled state; the black circles show the same properties in the suddenly cooled material, the letter A indicating that the metal has been cooled suddenly by a blast of air; the letter O that it has been cooled by plunging in oil; and the letter W that it has been cooled by quenching in water. Let us confine our attention to manganese steel containing from nine per cent. to fifteen per cent. of manganese.

As before, we see that the increase of elongation is much greater than that of tensile strength; in short, the sudden cooling is more markedly a toughening than a strengthening. Next, we note that, in general, the more sudden the cooling, the greater the strength and the elongation. Air cooling, the least rapid, gives the spots next above those of the natural state; oil cooling, next in order of rapidity, gives the next higher spots, while water cooling, the most rapid of all, gives in general the highest spots of all.

Next, what is truly remarkable, that in many cases these lines are nearly straight and parallel from end to end, show-

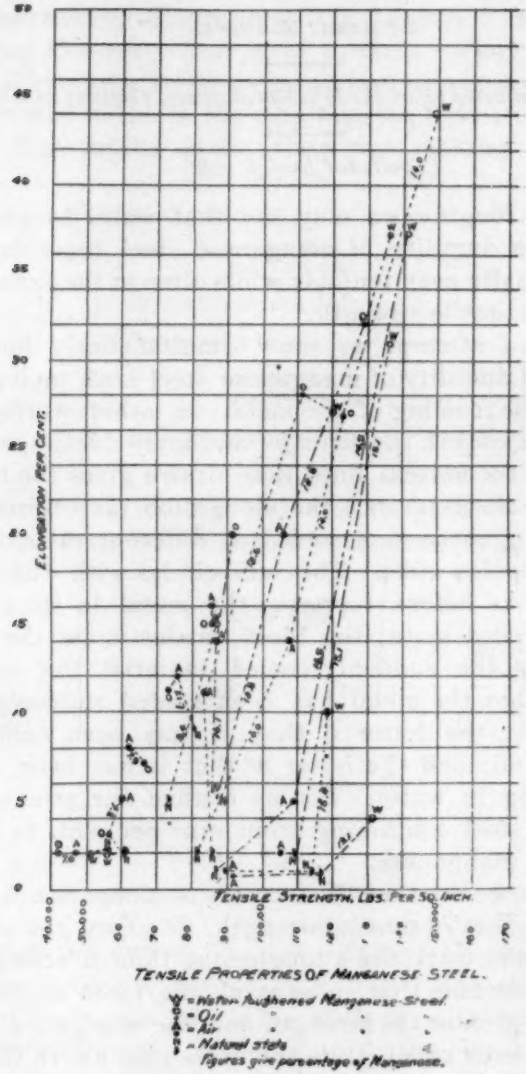

ELONGATION PER CENT.
TENSILE STRENGTH, LBS. PER SQ. INCH.
TENSILE PROPERTIES OF MANGANESE STEEL.
W = Water-hardened Manganese-Steel
O = Oil
A = Air
N = Natural state
Figures give percentage of Manganese.

FIG. 9.

ing that the ratio of increase of strength to increase of ductility is nearly constant for varying accelerations of the rate of

cooling, and that this ratio is the same, roughly speaking, for manganese steel of different compositions. This certainly seems to indicate that the increase of strength and of ductility are, in the main, due to one and the same ulterior cause. It may be that sudden cooling prevents some change which occurs during undisturbed slow cooling, some change which requires a considerable length of time, and which weakens the metal and lessens its ductility: that at a high temperature the metal assumes a condition which, if preserved by sudden cooling, assures strength and ductility to the cooled metal; while if we cool it slowly, some slow change, decomposition, re-composition or re-arrangement occurs, yielding a relatively weak and brittle substance.

But this explanation may be very far wrong, and, if it be right, we certainly do not know what the nature of the supposed change is. A change in the chemical condition of the carbon has been traced to sudden cooling; but this change does not readily explain matters. Sudden cooling changes most of the carbon of carbon steel from the "non-hardening" to the "hardening" state; and the hardness and brittleness of suddenly cooled carbon steel are usually attributed to the presence of this hardening carbon. In slowly cooled manganese steel the carbon exists in both the hardening and the non-hardening state; sudden cooling increases the proportion of hardening carbon, a change which would be expected to make the metal more brittle, instead of very much more ductile as it actually becomes.

I have thus far spoken of the effect of the rate of cooling on the ductility and strength of manganese steel. But the temperature from which sudden cooling occurs also affects these properties; and in general we may say that the higher the temperature, provided it does not rise above moderate whiteness, from which the metal is suddenly cooled, the stronger and more ductile will it be. In short, violence of cooling, both as regards the rate of cooling and the range of temperature passed through, strengthen the material and increase its ductility.

But here a caution. Pieces of a very ductile material may themselves be locally brittle, locally incapable of endur-

ing much distortion without rupture; pieces of a strong material may themselves be relatively weak. Notch a piece of cloth, and you may easily rip it across, though, if unnotched and twisted up into a rope, it would hold five tons. Nick a bar of steel, and a light blow will break it; file away the sides of the nick, and round and smooth the surface there, and you will find the remaining metal still strong. Thus, a crack causes the material to yield to trifling stress, by concentrating that stress into a limited region.

Now, we all know how easy it is to crack common steel when we harden it by plunging it into water while red-hot. And we know that these cracks are caused by the difference between the rates at which outside and inside cool.

The outside cools rapidly, and hence tends to contract rapidly; the inside cools much less rapidly; hence it contracts less rapidly, and thus opposes the effort of the outside to contract, and to reach the dimensions which it would naturally have at the existing temperature. The resistance of the inside thus, in effect, violently stretches the outside, and may stretch it so far as to crack it.

We all know that pieces whose shape causes great and sudden differences between the rate of cooling and contraction of different parts, and especially of adjoining parts; that is to say, pieces of suddenly and greatly varying thickness, are especially liable to crack in quenching.

Much the same holds true of manganese steel, though in an incomparatively smaller degree. While the metal is so ductile as to endure without cracking the distortion due to rapid cooling, yet extremely violent cooling, though it may give to the material itself its greatest strength and ductility, may yet, in case of castings whose shape or size favors cracking to an unusual degree, cause slight surface cracks, which, if they be not removed, may in themselves locally lessen the strength and ductility. Hence, the piece which has thus been very violently quenched may be likened to a piece of copper which has been nicked; the material is extremely ductile, but there is a local defect, which locally impairs ductility, and so weakens the piece as a whole, just as a weak link weakens the chain as a whole.

Hence it may be best, especially in treating thick pieces of cast manganese steel of irregular section and greatly varying thickness, to cool at a moderate rate, as for instance, by exposing to a blast of cold air, or by repeatedly dipping into water and drawing out again into the air. Naturally, this is especially true of unforged castings whose ductility, and hence whose power of resisting the temporary distortion arising during violent cooling, cannot be expected to equal that of forged pieces. Indeed, I have never known even the most violent cooling to injure forged pieces thus.

Forging.—In heating ingots of manganese steel of usual composition prior to forging them, their temperature must be raised very gradually. The metal conducts heat so slowly that, if exposed when cold to a high temperature, the outside becomes extremely hot, and hence expands greatly, while the interior remains almost cold. The fast expanding outside thus stretches the slowly expanding interior, and may stretch it so much as to crack it. Obviously, it is far better never to allow the ingot to cool, but to place it while still hot with the initial heat of casting, in a hot furnace, and simply leave it there till its interior is well solidified.

Once the material has been forged, however, it may be reheated much more suddenly, without danger of cracking.

For forging, the metal is brought to a light red heat, and at first *saddened;* that is, made compact with light blows; thenceforth it may be struck heavily. But the hardness which it shows when cold persists even at bright redness, and more work, that is to say more and heavier blows, are needed in forging it than most steel requires. For those familiar with working very hard steel, the whole may be summed up by saying that manganese steel behaves in forging like carbon steel containing about 1·25 per cent. or even 1·50 per cent. of carbon.

Manganese steel may be rolled hot into sheets as thin as No. 18 gauge, 0·049 inch, without special difficulty; and it has been rolled hot to No. 28 gauge, 0·014 inch, but with difficulty, for very frequent annealing is needed. It has been rolled cold into much thinner sheets, but it

hardens quickly in cold rolling, and must be annealed often.

It has been drawn into wire, 0·0105 inch thick, or of No. 31 B. W. G., No. 30 American wire gauge.

Machining.—Manganese steel of usual composition, while unalterably hard, is yet not so intensely hard that we cannot cut it. For cutting it in lathe or planer, the hardest of carbon or chrome tool steel should be used, and the cutting tools should be made as hard as fire and water will make them. Tools made of Mushet's and other self-hardening steel do not cut it readily, as they lose their edge by "slipping." Of course, the cuts must be very light, and the feed very slow. Exact comparative data are not at hand; but such information as I have indicates that it takes about four times as long to machine manganese steel as common carbon steel. This of course does not mean that it costs four times as much.

In general, it is important to bring the metal while hot as closely as possible to the desired shape, so that but little machining may be needed. It may be shaped by drop forging, hydraulic forging and other special means. It may often be cut advantageously when hot by means of a circular saw, as for instance in removing sinking heads.

In some cases cold rolling and other forms of cold working may be applied to manganese steel, in lieu of machining. For, while it certainly does not work as easily when cold as common soft steel, yet its disadvantage in this respect seems much less than in cutting by means of common steel tools.

In many cases, too, it may be punched or pressed cold to shape. When only a little of the metal is to be removed, manganese steel may be ground advantageously with an emery wheel. No special precautions are needed, beyond running the wheel rather slowly, as in grinding hardened steel. It costs more to grind manganese steel than to grind carbon steel when unhardened, but decidedly less than to grind hardened carbon steel.

Uses.—Let us next consider the actual and prospective uses of manganese steel.

Its most important single use is for the pins which hold the links of dredgers of the elevator or bucket class, some 4,000 of these pins having been made in the last two months of which I have advices. For these pins a strong and at least moderately tough material is needed, and at the same time one that resists abrasion well, as the sand and grit between the pin and the link in which it turns cut

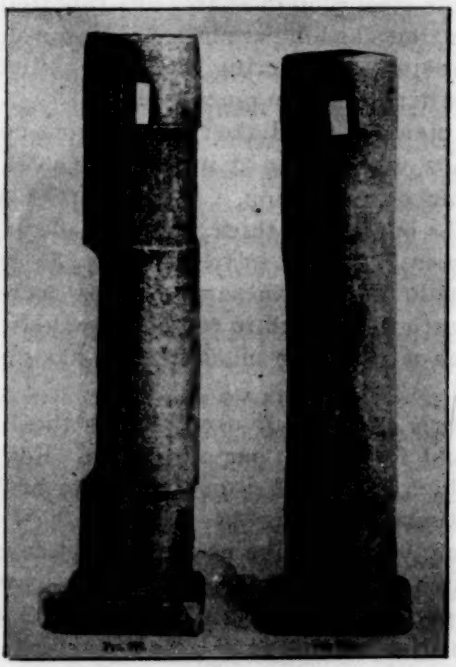


FIG. 10.

sharply. *Fig. 10* shows how much better manganese steel resists abrasion under these conditions than the carbon steel with which it competed. The manganese-steel pin, that which is least worn, has endured more than thrice as much use as its neighbor.*

* Since this lecture was read manganese steel dredger pins at Belfast have shown like remarkable endurance, wearing only one-tenth as fast as carbon-steels pins simultaneously used.

In other cases of which I have late reports, equally remarkable results have been reached. At Preston, in England, a full set of manganese-steel pins, after working for eighteen months in sand and gravel, had worn away only about one-eighth of an inch, or only about one-eighth as fast as common steel pins. Manganese-steel dredger pins at Hull, England, are reported as wearing about one-sixth as fast as those of common steel.

Manganese-steel plough shares are reported as wearing six or seven times as long as chilled cast-iron shares. This is rather surprising, considering that the chilled cast iron is certainly harder than manganese steel.

The side plates of the Blake crusher, those between which the jaw plays, when made of manganese steel, have shown great resistance to abrasion. These particular plates are seven-eighths of an inch thick. When made of hard carbon steel, they were worn out in two months; in crushing granite, when made of manganese steel, they were worn away only one-fourth of an inch in ten and one-half months. In other classes of crushing machinery, it has given excellent results.

Other fairly established uses are for the links of chain elevators, and for certain parts of safes. For the latter a material which can neither be drilled nor broken seems to offer exceptional advantages.

Of the many prospective uses of manganese steel I will notice but two, for armor plate and for car wheels.

Manganese-steel armor plates two inches thick have been tested under the conditions of actual warfare. From these tests it is calculated that, in order to offer the same resistance as a manganese-steel plate, a wrought-iron plate would have to be seventy-seven per cent. thicker, and a carbon steel plate forty-eight per cent. thicker.

We cannot yet tell whether manganese steel in very thick plates, such as are used for the sides of war ships, would behave as well as it did in these trials; but they certainly seem to commend it for the light plates with which vessels' decks are armored, and for the light shields which protect the gunners.

For railway car wheels we need a material which, like manganese steel, is so hard that it will not wear away under the friction of the brake-shoe; and yet is so tough that it will not break when it hammers under full load and at full speed against frogs and crossings.

Twenty-two manganese-steel wheels, thirty inches in diameter, on one of the New England railroads, ran from 131,499 to 188,179 miles, or on an average 168,453 miles, before the first turning.

This is nearly seven times the average mileage of chilled cast-iron wheels on this particular road, where the conditions are very trying owing to frequent stops, and the consequent frequent application of the brake. The mileage of these manganese-steel wheels is nearly six times the reported average life (29,074 miles) of cast-iron wheels on the Boston and Albany Railroad. The general belief is that chilled cast-iron passenger wheels, thirty-three inches in diameter, run on an average 60,000 miles before removal; which is about one-third the mileage of these manganese-steel wheels before their first turning.

The mileage of composite or steel-tired wheels is much greater than that of chilled cast-iron wheels, though the steel tire of the composite wheel is very much softer than the cast iron. That of 720 steel-tired wheels on the Boston and Albany Railroad was 111,804 miles before the first turning; the average mileage of these manganese-steel wheels is thus fifty-one per cent. greater than that of these composite wheels before their first turning.

The first cost of the manganese-steel wheel, which is a simple casting, is much below that of the composite wheel. The cost of the wheelage, or wheel service, consists mainly of the first cost of the wheel and of the interest on this first cost. Calculations which I have made, but with which I will not to-night trouble you, show that the manganese-steel wheel is likely to be much cheaper per 1,000 miles run, than the composite wheel.

I believe that the manganese-steel wheel is not only incomparably safer than the chilled cast-iron wheel, but,

all things considered, really decidedly safer than the composite wheel.*

Its enormous and extremely constant electric resistance, coupled with its cheapness, as compared with German silver and platinoid, should give manganese steel important applications in electrical engineering.

RESISTANCE TO SHIP'S MOTION: A NATURAL LAW NEWLY DISCOVERED.

By F. M. F. Cazin.

How natural, how uncomplicated, how simple and beautiful does the sail-boat glide along on the waters, that reflect the azure color of space and the shady tints of its rivals—the clouds.

There is a power moving boat and clouds. And there is a resistance to the movement of the one and the others, that is overcome by such power, the former yielding to the latter.

Do scientists at this great age of intellect and invention possess the faculty of precisely and intelligently measuring the resistance just spoken of?

In all of his weak moments in life the engineer takes refuge to his pocket book, in which there is gathered the wisdom of ages. Let us see what these treasures of knowledge in mechanics and engineering tell us on the subject of resistance to ship's motion.

* A widely-circulated statement of the number of steel tires broken on the railroads of the German Empire in the years 1884 to 1889, inclusive, reports many manganese-steel tires as breaking. But the term "manganese steel," as here unjustifiably used, refers to a wholly different material from that described in this paper; indeed, to a true carbon steel merely containing a little more manganese than usual, but I believe never more than two per cent.; certainly nothing like the percentage of manganese which would entitle it to be classed with the manganese steel forming the subject of this paper. Some of this pseudo-manganese steel, lately examined, contained only 0·60 per cent. of manganese.

John W. Nystrom's book specifies the resistance to the movement of ship as follows (p. 449):*

$$R = 2{\cdot}858\ \mathfrak{M}^2\left[Ms\,(0{\cdot}9\ \sqrt{\sin^3 a} + 0{\cdot}1\ \sqrt{\sin^3 b}) + \frac{A\,k}{\sqrt{L}}\right]$$

R signifying the resistance to the ship's motion in pounds.

Ms signifying the transverse major section of immersed part of ship.

a signifying the mean angle of resistance to the vessel moving in water.

b signifying the mean angle of delivery of the aft-displacement.

$\mathfrak{M}$ signifying the speed in knots per hour.

A area (surface) of the immersed hull.

k coëfficient of friction in pounds per square foot of the immersed surface (A) of the vessel.

L length of vessel in loadwater line.

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* John W. Nystrom, C.E., states (p. 448, ed. 1880), that this and other equations relating to the parabolic construction of ships (primarily based on resistance to ship's motion) are based on his equation No. 1.

$$\beta = b\left[1 - \frac{y^n}{l^n}\right]^{\frac{1}{n}}$$

for "any ordinate at distance y from M.," but that when developed into combinations with the form of ship "this fundamental value becomes a very complicated affair, which required *a separate treatise on ship-building for proper explanation.*" In fact, Nystrom's equation is originally based and built up on the fundamental values for resistance to immersed motion, as they were universally accepted, and as they were stated by Weisbach, (*Pocket Manual*) by Rankine (*Applied Mechanics*, p. 598), and W. C. Unwin, (*Encyl. Brit.*, 9th ed., "Hydro-Mechanics," p. 545), when identical symbols are used for identical values, in the equation

$$R = a\,.\,\delta\,.\,M^n\,\frac{v^2}{2g}$$

these three authorities yet differing one from the other, by Weisbach expressing by a ($= \xi$) a coëfficient (unknown) of form or obstacle, and Unwin expressing by a (K) the "ratio of the plate (face of solid) to the opening of pipe (transverse section of water jet), and Rankine expressing by a (K) a coefficient (unknown) of form. And Nystrom, not acquiescing in such interpretation of either of the three authorities, substitutes for the value a the two values a and b for the "mean angles of resistance (fore) to the vessel moving in the water" and "of delivery (aft)."

And I find

$$\frac{A\,k}{\sqrt[4]{L}}$$

to be used for measuring the effect of friction, and the coëfficient k therein to be assumed as varying between 0·003 and 0·020 or as 1 : 6 . 6 . . .

The valuation of resistance to submerged motion thus expressed rests on a fundamental assumption, which is best and most opportunely expressed in the words of a master of generally acknowledged authority in theoretical mechanics, viz: Prof. Julius Weisbach, he states:

"Though we cannot specify the value of these resistances *a priori*, we may nevertheless assume, on account of the great similarity of conditions with the *percussion* resulting from *isolated jets*, that at least the general law for *percussion by an unlimited quantity of water* does not vary from the law for the *percussion* resulting *from isolated jets*."*

But this assumption has given very little satisfaction to those theoretical mechanicians, including Weisbach himself, who undertook the task of evolving its consequences for either theoretical or practical purposes. Text books of natural philosophy, mechanics and nautics remained in consequence singularly deficient in their statements regarding the *resistance to relative movement of solid and medium*, some omitting altogether to mention the subject, others treating it with superficialty only.

The writer's individual persistency to go to the bottom of the question had nought to do with nautics. A concurrent question for which nowhere a satisfactory solution could be found had propounded itself, namely, the question:

With what velocity would the different particles of disintegrated metallic ore fall in water? Practice told, that different particles fell with different velocities, but the savants, who in volumes of learned reasoning had undertaken to solve this question, had all started from an assump-

* Art. 537, vol. 1, pp. 1179–80, 5th ed., revised in 1875 by Gustav Herrmann, Professor at the Polytechnical Institute at Aachen (Aix-le-Chapelle).

tion that appeared on investigation to be untenable, and from a therefrom resulting valuation, such as here above stated, and for which an intelligent or adequate demonstration was not available. And as a consequence they as well as mechanicians, who cultivated other familiar fields of original research, arrived all at the conclusion, that their results were unsatisfactory. And yet the question at issue seemed otherwise to be an extremely simple one. The force of gravitation (weight), that caused the mineral particle to fall was known in each given case. Had it not been for the resistance to the solid's (fall) motion in the water, (medium) all the particles would have fallen with the same identical velocity ($= v$) as

$$v = \sqrt{2gS}$$

g, being twice the distance all matter on earth will pass, when free to fall (in vacuo), in the first second of such fall (toward the centre of the earth).

S, being the total distance of fall (head) under acceleration of gravity.

What this resistance (R) to motion of solid in submersion really be, and what influence in consequence it produced in varying (for different solids) their velocity of fall in submersion, was the main question therefore in this matter, as it is the main question in nautics and navigation.

One learned authority (P. von Rittinger), standing high in an honored public professional office in Austria had written volumes* on this question, and as a main result confessed, that a mere theoretical development of laws for motion in submersion be insufficient for establishing a theoretical foundation to the art of mineral dressing, but that experimental coëfficients be required for completing such foundation. And another learned authority (von Sparre†), of equally high professional office in Prussia found Rittinger's results to be erroneous. And yet neither of the two doubted the correctness of the fundamental assumption, as

* *Lehrbuch der Aufbereitung*, also *Erfahrungen*.

† *Contributions to the Theories of Mineral Dressing*.

it is laid down in Weisbach's, Rankine's and Unwin's expressions, as quoted, nor did they doubt the sufficiency of these expressions, for building thereon an attempt on their part to solve the problem before them. But, when von Sparre, the critic, attempted on his part to really solve the problem, employing only a different method of construction on the same foundation,* he arrived at a conclusion, which he stated as follows: "That these results (von Sparre's) are so complicated that their expression in correct values is impossible."†

That both these savants failed in their attempt to evolve satisfactory results, was evidently caused by the absence of a correct and complete measurement of the resistance to the movement of a solid in a liquid medium, this is of a simple, intelligible valuation of such resistance, that would hold equally good, whether it be applied to the particle of rock, when operated with on a jigger, or whether it be applied to the ocean-going steamer for finding the precise power that would propel it at a stated speed.

The resistance experienced by both is of the same nature and character, though the power causing the particle of rock to fall is its gravitation, while the steamer has to employ energy set free in combustion, and modified into kinetic energy for bringing about her movement. And the purpose of research is in the one case the ascertaining of comparative velocities of fall in submersion, and in the other case it is the ascertaining of not only the precise value of resistance experienced and consequent power to be applied to produce movement, but also of the most rational method of applying power for such purpose.

It might therefore be presumed, that what the savants dealing with particles of rock had failed to find or to develop, would surely be made clear in the hand-books for nautics and navigation, in the service of which so many

* "The mathematics may be compared to a mill of exquisite workmanship, which grinds your stuff to any degree of fineness, but nevertheless what you get out depends on what you put in." Prof. Huxley. Compare F. A. P. Barnard, *The Metric System*, ed. 1872, p. 100.

† Page 9 of *Beitraege zur Theorie der Erz-Aufbereitung.*

sturdy human intellects have been at work. But the crop of information that could be gathered in nautical literature proved of even less really scientific value than that possessed by the researches made by metallurgists. If the latter had discussed the valuation of resistance to motion in a medium, because what value they found therefor in general mechanics did not answer their purpose, mariners had remained contented, and had not proven themselves inquisitive beyond what could be read in their text books to the extent to cause the sole inquiry ever seriously attempted, the one mentioned on the following pages to terminate in an advice to experiment in all given cases with the specified model of the ship to be built.

All of what nautics and navigation possess and use in the premises at this date is based on the assumption, as so clearly stated by Weisbach, of similarity of conditions between the effect of the water jet striking under pressure of head an opposed solid face, and the effect of the great mass of water striking the moving ship. But the same as the metallurgists, so those learned in nautics failed to prove mathematically the correctness as well as the extent of such similarity, or the real cause, on which such similarity rests, or the true nature of the conditions as they exist. And, although I shrink back from stating it, the true value for the effect of the water jet itself seemed but vaguely and even erroneously defined.

It is on the assumption of *percussion* by the medium, that angles of bow (a) and of stern (b), the transverse major section (Ms) and the area of surface (A) and friction measured thereby (k), besides constructive length of ship (L), are made conditional and contributive to the valuation of resistance to ship's motion. And yet I find that since Morin, in 1833, had presented to l'Académie de Paris (t. iii) his *Nouvelles Expériences sur le Frottement*, the scientists of the world had acquiesced in the following facts:

(1) Friction (its effect) is proportional to pressure.

(2) Pressure considered, friction (its effect with smooth faces) is *not* proportional to surface being in contact.

(3) Friction is *not* proportional to, but independent of, velocity of contact movement.

From these facts it appeared, that whatever valuation there had been given to friction by

$$\frac{A\,k}{\sqrt[4]{L}}$$

without accounting for pressure (weight) but qualified by surface (A) and length of body (L) must be erroneous, rendering consequently the entire solution of resistance to motion in submersion (as thereby qualified) erroneous.

From these facts it seemed to be indicated, that, with weight accounted for, friction as its product would already have found its consideration, so much so, as neither surface nor velocity as conditional to friction appeared to be of any influence beyond what *weight* constituted as a condition to friction; and when considering solids with smooth faces, relative motion of solid (smooth faced) and liquid medium appeared not to require a contributive valuation for friction at all, because between a wetted surface of a smooth-faced solid and the liquid mass there is surely no friction or resistance in excess of what the moving parts of the liquid mass itself exercise on one another, and what there is of this, would evidently be included under the caption of head resistance and under that of the assumed condition thereto, viz: viscosity, if such values should really appear as conditional and essential.

If thus it appeared indicated, that the value of friction and of surface be subordinate to the value for weight, experiments made in a supplementary way to those of Morin, proved that *form* (shape) *of face* in the solid (fore and aft) remained *as such* without influence on the resistance to relative motion, but that the medium (water, air, etc.) itself makes correction in all cases, where the form of the solid does not conform to the most favorable conditions for minimal resistance to relative motion, by adding of its own to the moving (relatively) volume, which added volume participates in the solid's relative movement, the resulting lines of the moving mass thereby conforming to those of the medium's molecular division lines.

If a solid with smooth surface and a form closely follow-

ing the lines of the medium's molecular division be considered, the consideration of both *friction* and *form of face* may therefore be omitted, as long as *weight* be considered. And in case the form of moving solid does not so conform, it appears to be the total relatively moving volume, in part solid and in part of medium, respectively, such total volume's weight, which properly comes into consideration.

What then appears to be really conditional to the measurement of resistance to relative motion of medium and solid, is properly represented by *velocity*, *weight* and *volume* of both solid and medium.

Nevertheless it appeared, that none of the scientists, working in the interests of the technical branches as mentioned, had as yet abandoned a valuation based on the erroneous coëfficients for friction, surface and face, a fact easily ascertained from existing technical literature, from which I shall quote a few specimens only.

In 1869, the British Association for the Promotion of Scientific Research appointed a committee to "inquire into the state of existing knowledge on propulsion and other features of ship's behavior." The committee's attempt to arrive at a precise measurement of the resistance to the ship's motion by the water proved so entirely unsatisfactory in its results, that W. Froude deemed it to be in mitigation of their ostensible failure, to propose in an appendix to the committee's report the substitution for all theoretical measurement of an experimental value, being obtained in each practical case occurring, by experimenting with the ship's model.

In 1873, the *Annual of the Royal School of Architecture and Marine Engineering* (p. 92) as a *résumé* of the report just mentioned and of Froude's appendix thereto makes the following statement:

"The resistance opposing the motion of any vessel is of two kinds—surface friction, and what is commonly called direct head resistance. The former of these is caused by the friction of the water against the vessel's surface, whereby it is partly thrown into small eddies and partly dragged along after the vessel in the form of 'wake.' This

resistance may for the present be supposed to vary with the square of the speed, and in comparison of similar vessels of different sizes, with the immersed area, *i. e.*, with the square of the dimension. Neither of these assumptions, as has been shown by Mr. Froude, is quite correct, but we will presently point out how, in deducing the resistance of a ship from that of a model, the error involved may be allowed for. If we take R to denote the resistance due to surface friction, l the dimension (length, say) v the velocity of any vessel, we may express the above algebraically by the formula

$$R = l^2 \times v^2$$

"The head resistance is caused partly by the distortion of the particles of water or viscosity, and partly by the production of waves. The former of these causes may be taken practically to vary, as $l^2 v^2$, when the vessels are not of very small dimensions, and may thus be considered to form part of R; it is by the latter, however, that the chief element of this part of resistance is formed, every vessel being accompanied by a wave having its crest near the bow and stern, and also by a series of subsidiary waves due to the inequalities in the form of the vessel's lines."

In 1885, Prof. R. H. Thurston, of Cornell University, when writing on "The Limit of Speed in Ocean Travel," specified the resistance to the ship's motion as follows:

"The resistance of a steamship or other vessel consists of two principal points:

(*a*) "The effort required to overcome the friction of the water on its wetted surface.

(*b*) "The force expended in producing the waves, that are seen arising about every ship in motion."

And the same author further specifies the two values by him given as conditioning the total value for resistance to relative motion by medium and solid, as follows:

(1) "The friction of hull is found to be very nearly proportional to the area of wetted surface.

(2) "The nearer the form of the ship approaches that of a hemisphere, the less must be the resistance due to friction, and between the latter shape and that elongated form,

which gives minimum head resistance, there must be some intermediate form, which will give the least total resistance.

(3) "The power demanded to propel any vessel at ordinary speed varies as the square of her length nearly, or as the area of the transverse major section and as the cube of the speed."

Besides the values for transverse major section—mean angle of resistance resulting from shape fore and aft, and surface as conditional to friction, the explanations here quoted introduce such values as: viscosity and waves.

Wolfgang von Goethe has Mephistopheles instruct Faust's pupil, that when the true conception is wanting, when he be unable to form a correct idea, to invent a new word to cover the case, which, with superficial humanity, would answer the same purpose, and as well, as a correct understanding would. The word "viscosity" (viscidity, stickiness, slabbiness) has so far answered just such a purpose. Just what value it represents in mechanics nobody has ever defined. It has had to stand for an unknown quantity.

Molecular adhesion lines, wave lines as peculiar to water will appropriately assist the nautical constructor to so construct the ship's bottom, that she conforms in her lines to those indicated by the water's natural (molecular) division lines, the most perfect construction being such, with which the ship's bottom does not drag along with it, when moving, a quantity of water, as if it were a part of the ship itself, either in front of her bow or in her wake. The further the ship's form is from such perfection, the greater will be the addition to the moving volume, and the resistance to the ship's motion will be increased, which is demonstrated by daily experience.

When "waves" result from the movement of the ship, their real cause is either in the ship's inadequate form, this is a form not conforming with the water's molecular division lines, or in the inadequate application of propelling power. Such part of the propelling power as causes waves on the surface, is lost as cause for progressive motion, a fact

that is practically demonstrated by action and effect comparatively of paddle-wheel and screw.

Such considerations as those stated on the preceding pages resulted in an attempt on my part to improve on the present teachings in applied mechanics, nautics, etc., that I had come to consider as erroneous, by substituting for indefinite, complicated and merely comparative values such others, as would be definite, concrete, simple and fully intelligent.

But I find that the attempt has brought me into conflict with those, who defend the contents of their text books as unimpeachable. Thus the ungrateful *rôle* of the reformer is imposed upon me, of which I cannot otherwise successfully acquit myself than by sound argument and precise, intelligent expression.

To capture the good-will of professionals it might be well to minutely describe the slow process of freeing oneself from the blinding influence exercised by preconceived notions and the equally slow evolution of new or different conception, but the great value of time in this hurrying age forbids the attempt.

I have to be contented, therefore, with a clear statement of what I claim to be true and a law of nature and with a concise argument in support of the claim, this is of my new method for measuring the effects of the movement of a volume of stable quantity and form in or relative to a liquid or fluid medium.

The following then are the newly proposed dogmas in theoretical and applied mechanics and in natural philosophy, nautics, aëronautics, dynamic metallurgy, astronomy, etc.; as by the writer proposed with all of their consequences and in plain view of the recognized, fundamental principle, that nought need be considered as true, but for which proof can be rendered from facts critically observed and repeatable in nature and by methodical, logically correct conclusions derived therefrom.*

* Compare: DeGavarelle, *A Protest*, 2d ed., p. 39. "What may be Known and What Not." New York: Polytechnical News Company, 28 Lafayette Place.

SIX NEW THESES IN MECHANICS.

The following six theses then express the new teaching:

(1) A solid moving in submersion a distance (d) equal to its own length, when measured in the direction of motion, displaces of the medium in inverse direction and for the distance of its own length (of travel) a volume ($= B$) equal to its own immersed or submerged volume, and when so moving any other distance (of travel), the solid moves the volume B of the medium in inverse direction of its own motion for the total distance of such travel.

(2) A ship progressing at any stated velocity per second causes the movement in inverse direction within every such second of a quantity of water being equal to

$$D = \frac{B}{d} \cdot v \text{ metric tons.}$$

B signifying the ship's immersed volume or buoyancy in cubic metres.

d signifying the ship's length measured in the direction of motion on her water line in metres.

v signifying the distance of her travel per second in metres.

(3) A solid in moving in a medium displaces permanently for a distance ($= d$), in inverse direction to its own motion, a volume of the medium equal to the product of its transverse average section ($= B/d$) and the distance of its travel, the transverse average section being as the solid's volume divided by its length, measured in the direction of its motion.

(4) A solid of non-uniform section transverse to the direction of its motion, when moving in a medium, displaces of the medium in inverse direction to its own motion permanently a quantity measured by its own transverse average section ($= B/d$) multiplied by the distance of its travel, and it also dislocates passingly and in a lateral direction another quantity of the medium, that is measured by the difference between the transverse major and average sections of the solid as one factor and the distance of its travel as the other factor, this additional quantity of the

medium being caused to passingly move or dislocate, but occupying the same position after the solid has passed, as it did previously thereto, and the quantity of the medium = distance of travel $\times$ B/d is inversely moved permanently for the distance (= d) (from fore to aft).

(5) The resistance to the movement of all solids in a medium is measured by the permanent displacement in inverse direction to their own movement of a quantity of the medium, which is the product of the solid's own transverse average section (= B/d) in the length of the solid's travel.

$$\left(= \frac{B}{d} \cdot v \text{ per second.}\right)$$

And the conclusions for the measurement of power, required to overcome the resistance thus defined, as drawn from these five theoretical assertions, are as follows:

It is the *quantity*

$$f\,v = \frac{B}{d} \cdot v$$

of the water for every second, which must *receive an impulse* to flow in a direction inverse to the ship's motion, and the impulse given to the water must be sufficient to cause its flow with the stated *velocity*. And this impulse is equivalent with the raising of the stated quantity

$$f \cdot v = \left(\frac{B}{d} \times v\right)$$

of water to an elevation

$$= S = \frac{v^2}{2\,g} \left(= S\frac{g}{2} = \left(\frac{v}{2}\right)^2 \text{ when } \frac{g}{2} \text{ is the unit for measuring distance.}\right)$$

It is, therefore, also true, that

(6) The power required for propelling a ship at a stated velocity per second (= v) is as

$$P = f\,v\,S = \frac{B}{d} \cdot v \cdot \frac{v^2}{2\,g} = \frac{B\,v^3}{d\,2\,g} \text{ kilogramme metres.*}$$

f signifying transverse average section $= \frac{B}{d}$

S signifying total distance of fall by acceleration of gravity;

B signifying the ship's immersed volume or buoyancy. When the total value is expressed in ton-metres, then B is expressed in cubic metres, but when the total value is expressed as kilogramme metres, then B is expressed in the corresponding of $0{\cdot}1^3{}_m$ = litres = kilogrammes;

d signifying the ship's length measured in the direction of her motion and on her water line;

v signifying the ship's velocity in metres per second;

g signifying twice the distance, which matter, when free to fall will pass in the direction towards the earth's centre within the first second of such free fall. This distance g, being as $g = 9{\cdot}78009 + 0{\cdot}05080\ sin^2\,\varphi$ (φ = geographical latitude) showing, that travel of ships for equal speed and distance requires less power on northern than on southern geographical lateral travel.

When movement in another medium than water is

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* A railroad train, say of sixty cars of equal weight, each twenty feet long, moves within one second a distance of 400 feet. When stopping again forty cars will be, where forty cars were before, virtually not moved at all, and twenty cars, that were at the rear end, are there no longer, but appear at the front end, though they be not the same cars.

With B as the total weight (in vacuo) of the train in metric tons, with d as the length of the train in metres, and with v as the distance of travel per second, $B\,.\,v/d$ represents the mass moved per second, and $B\,.\,v^3/(d\,.\,2\,.\,g)$ represents the power required to move the train horizontally, when running with lubricated cool axles.

under consideration, the factor for density of medium must become part of the equation, which then will read

$$R = \delta \cdot \frac{B}{d} \cdot v \times \frac{v^2}{2g}$$

Comparing this equation with the equations representing the same value as developed by Weisbach, Rankine and Unwin, and expressed by uniform symbols with the exception of a, for which all three authorities have an essentially different interpretation, we find their equation to read

$$R = \delta \cdot Ms \cdot a \times \frac{v^2}{2g}$$

In both equations due consideration is accorded to the general character of the total value as that of "momentum," viz: as the product of mass and movement. The factor conditional to movement, representing gravitation by $v^2/2g$, is in both equations the same.

The factor "mass" is measured by the three authorities by

$$\delta \cdot Ms \cdot a$$

for which I make the attempt to substitute

$$\delta \cdot \frac{B}{d} \cdot v$$

this latter value representing a volume and corresponding precise weight of the medium, in which the movement of the solid takes place, and conditioned on the form of the solid either conforming, as in ships, to the molecular division lines of the medium, or on adequate but simple addition to such volume of what of the medium joins the solid in relative movement by adapting the moving form to the natural and peremptory lines of molecular division of the medium.

The value δ for density in both is identical, and as water is under consideration, when δ is $= 1$, and on account of identity this value may be dropped out of consideration.

The parallel remaining values then are:

$$Ms \cdot a$$

and

$$\frac{B}{d} \cdot v$$

The essential difference between these parallel values consists in this:

The value

$$f \cdot v = \frac{B}{d} \cdot v$$

signifies the precise volume and corresponding weight of the medium, which passes any stable point in the line of the ship's travel in inverse direction to such travel within the time limit of one second, and therefore is a true expression for mass per second and in consequence allows for the total value of resistance a concrete expression in kilogramme metres.*

Let us investigate the meaning and significance of the older valuation of "mass."

It first then appears, that the three authorities quoted are not authority for the same valuation.

Weisbach's interpretation of $a\ (= \xi)$ is:

> "A coëfficient (experimental, unknown) of form of obstacle."

Unwin signifies by $a\ (= K)$:

> "The ratio of the plate (face of solid) to the opening (transverse section) of pipe (medium causing percussion), and

Rankine expresses by $a\ (= K)$:

> "A coëfficient (unknown) of form."

And Nystrom has been satisfied with none of these three authoritative valuations, but substitutes the value:

> "a by the two values a and b for the mean angles of resistance *fore* and *aft*."

With none of the four authorities $Ms \cdot a$ signifies a well-defined volume and weight. The factor a renders the product $Ms \cdot a$ dependent on other values to be looked for outside of the equation itself. But with all four authorities the value $Ms \cdot a$ represents resistance to per-

* Compare the preceding footnote relating to railroad trains.

cussion, and with all four authorities *Ms* stands for "transverse major section," as the condition to measuring continuous resistance.

In conflict therewith I make "transverse average section" conditional to measurement of continuous resistance, and the value for "transverse average section" is not, as *Ms* is, relating to a single set of constructive lines, but it relates to *all solids* of whatever different constructive lines, and is conditioned on their immersed or submerged volumes (B) being the quotient in said volume by the solid's length (d), measured in the direction of its movement, as divisor.

It is by the method of measuring the length d, that my equation not only measures the resistance to the progress of ship, when she proceeds on her way normally, this is in the direction of her greatest length, but measures resistance to her movement also, when she is moving diagonally or even in the direction of her shortest dimension.

In none of the older equations except Nystrom's is there any connection made with distance of travel ($t\ v$) or distance per second (v).

My equation accounts directly and concretely for the influence of distance as conditional to measurement of resistance.

I may therefore justly claim, on condition of proof being rendered for the facts as they are expressed by my equation, that for an indefinite, incomplete and comparative valuation of resistance to motion in a medium, dependent on unknown experimental coëfficients, I have substituted a definite, in itself complete and independent value for movement of a stable volume in a liquid or fluid medium, a value expressed in precise equivalents of kinetic energy.

[*To be continued.*]

PROCEEDINGS

OF THE

CHEMICAL SECTION

OF THE

FRANKLIN INSTITUTE.

[*Stated meeting, held Tuesday, February 21, 1893.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, February 21, 1893.

Dr. D. K. Tuttle, Vice-President, in the chair.

A letter from Prof. Henry Trimble was read nominating Mr. Josiah C. Peacock, 3909 North Fifth Street, Philadelphia, for full membership in the Section. As a result of the action of the Committee on Admissions, Mr. Peacock was declared elected.

Dr. Wahl reported that at the special meeting called by the President to consider the adoption of resolutions of respect to the memory of our fellow-member, Dr. F. A. Genth, recently deceased, a committee was appointed to draw up these resolutions, which were published in a number of the leading daily newspapers of Philadelphia. On motion the Section voted that the Treasurer be authorized to pay the bills incurred by the committee in the publication of these resolutions which read as follows:

Resolved, That the members of the Chemical Section of the Franklin Institute have heard with deep regret of the death of their distinguished fellow-member, Dr. Frederick A. Genth, whose eminent services as an investigator have added lustre to American science.

Resolved, That a committee be appointed to prepare a suitable memoir of the deceased for publication in the proceedings of the Section.

Resolved, That as a mark of respect, the Section be requested to attend the funeral in a body.

A paper on "Artesian Wells" by Professor Carter, of the Central High School, was read by title and referred for publication.

Dr. E. H. Keiser, for Miss Mary Bidwell Breed, of Bryn Mawr College, read a paper on "Phenolphthalein and Methylorange." The article was interesting and was well received. Quite an animated discussion as to the relative merits of the two substances as indicators was called forth and was participated in by Mr. Rowland, Dr. Keiser, Mr. Pemberton, Mr. Haines, Dr. Keller and others.

The paper was referred for publication.

Mr. S. W. Young, of Swarthmore College, then made a report of the most important results obtained in the field of stereo-chemistry up to the

present time. A number of the theories, offered to explain certain interesting cases of isomerism, were stated and illustrated by models showing the supposed special relations of the atoms contained in the compounds considered. The paper was attentively received and on motion the Section voted that it be published in the *Journal.*

Adjourned. WM. C. DAY, *Secretary.*

A NEW PROCESS FOR THE MANUFACTURE OF MANGANESE ON THE COMMERCIAL SCALE.

BY WM. H. GREENE AND WM. H. WAHL.

[*Read at the stated meeting of the Chemical Section, held January 17, 1893.*]

Within a few years manganese has assumed considerable importance as a constituent of several alloys, and the purest manganese of commerce as well as the richest ferro-manganese have been unsatisfactory for the preparation of these alloys by reason of the high proportion of carbon invariably present.

About two years ago we were induced to undertake the search of a process for the manufacture on a commercial scale of metallic manganese that would contain a minimum of detrimental impurities and be absolutely free from carbon. Before describing the process which we have elaborated, we will review briefly the history of the element.

About 1774, Scheele and Bergmann demonstrated that the metallic radical of manganese dioxide is different from iron, and John* isolated the new element by heating a mixture of manganese carbonate and oil, powdering the resulting mass, again mixing it with oil and strongly heating in a brasqued crucible.

St. Claire Deville† modified this process as follows: He reduced pure artificially prepared dioxide to red oxide; mixed this with sugar charcoal in insufficient quantity to reduce the entire quantity of oxide, and heated the mixture in a lime crucible to the highest temperature of a wind furnace.

* *Gehlen's Jour. Chem. Phys.*, **3**, 452.

† *Ann. de Chimie et de Physique* [3], **46**, 182.

Brunner* heated manganese fluoride, or a mixture of manganese chloride and calcium fluoride, with sodium in clay crucibles.

Giles† prepared a manganese amalgam by the action of sodium amalgam on a concentrated solution of manganese chloride, and expelled the mercury by heating in a current of hydrogen, thereby obtaining pulverulent manganese.

Bunsen‡ obtained deposits of metallic manganese by electrolyzing a concentrated solution of manganous chloride.

The first attempt to produce the metal in considerable quantity appears to have been made by Hugo Tamm§ who in 1872 published the results of experiments made on certain modification of John's method. Native dioxide was reduced by heating with powdered charcoal and oil in the presence of silicious and fluorspar fluxes in graphite crucibles.

The problem presented to us was the reduction of a native oxide of manganese, for it is apparent that the expense of preparation of halogen compounds of the metal and their subsequent reduction would preclude the possibility of applying such a method to manufacturing on a commercial scale.

At the outset of our work it became evident that the first step in the process would be the purification of the ore from iron, which would inevitably be reduced in the reduction of the manganese and could not then be removed from the metal. Magnetic separation appeared to be the cheapest and most effective method, and we made exhaustive experiments in this direction, the ore being treated in all states of division and in all conditions of oxidation, between that of the natural ore and that in which the manganese was reduced to manganese monoxide and the iron to metallic iron. We were compelled to abandon the method entirely, because the iron and manganese are so intimately associated

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* *Pogg. Annalen*, **101**, 264.

† *Philosoph. Mag.* [4], **24**, 328.

‡ *Pogg. Annalen*, **91**, 619.

§ *Chem. News*, 1872, 111.

in the ore that no satisfactory separation can be accomplished by the magnet.

We then tried various electro-chemical methods, the ore being made the anode of baths containing sodium chloride solution, ferrous sulphate, dilute sulphuric acid, etc. By such means a certain proportion of the iron may be removed, but the separation is slow, and is far from complete when the manganese oxides begin to be attacked.

Convinced that only a chemical method would answer the purpose, we found after a number of experiments that nearly all the iron can be removed from rich manganese ores by digesting the pulverized ore with about thirty per cent. sulphuric acid near the boiling point, while the manganese is practically unattacked. As an illustration of the effectiveness of the process, we may state that in a few hours the percentage of iron may thus be reduced from five or six to a few tenths, with a loss of not more than one per cent. of the manganese present. The copperas that may be obtained by treatment of the waste acid with scrap iron, will pay the cost of purification of the ore.

The reduction of the ore has been a perplexing problem. While it has never been denied that reduction by carbon in any form yields a metal containing a considerable proportion of the reducing agent, the literature of the subject indicated that this combined carbon might be removed by fusion of the metal under a layer of manganous carbonate or manganous oxide. Thus, Tamm* claims to have obtained, from a pyrolusite containing 79·5 per cent. Mn. and 6·5 per cent. F_2O_3, a metal containing

Mn.	96·90
Fe	1·05
C	0·95
Other elements	1·10

and by refining this with manganese carbonate to have raised the proportion of manganese to 99·91 per cent. Other investigators admit the presence of more carbon in the product, but still claim that it may be removed by treatment

* *Chem. News*, 1872, 111.

with manganese carbonate. Our experiments show that the reduction by carbon takes place readily, and only after frequently repeated experiments, in which the proportions of oxide and carbon and the character and proportions of flux employed were varied through wide ranges, did we come to the conclusion that it is impossible by this method to prepare a metal containing less than about six per cent. of carbon, and that it is equally impossible by fusion with an oxidizing agent to remove carbon thus combined with manganese. The results of experiments recently published by Guntz* explain clearly these phenomena. He finds that carbon monoxide is rapidly decomposed by manganese at a red heat, carbon and manganese monoxide being formed. It can then be readily understood why carbon free manganese cannot be made in the electrical furnaces nor in graphite crucibles.

From all these facts we have been led to infer that the reduction of manganous oxide by carbon yields not manganese, but a definite carbide having the composition Mn_3C. We propose investigating this point in the future.

It then became evident that the problem could only be solved by a reduction taking place in the entire absence of carbon. Tentative experiments having given no encouragement to hope that an electrolytic method depending on the decomposition of fused baths of manganese chloride or manganese fluorides mixed with other chlorides and fluorides could be devised, the only alternative became a purely chemical process, the details of which were worked out during the progress of the laboratory work. The importance of these details will become apparent as we describe the steps of our process.

The pulverized manganese ore purified from iron, or containing less than one per cent. iron, is exposed to the action of reducing gases at a temperature approximating redness. All the manganese is thus converted into greenish-grey manganese monoxide, which must be allowed to cool out of contact with air to prevent oxidation to red manganoso-manganic oxide.

* *Comptes Rendus*, **114**, 115.

The monoxide is then mixed with about eighteen per cent. of its weight of granulated aluminum and a suitable flux and the mixture is heated to a temperature near the melting point of cast iron in magnesite crucibles. The flux may be silicious or a mixture of lime and fluorides, or lime alone. As soon as the temperature of reaction is attained the mass promptly fuses and must be poured from the crucible while at its maximum temperature. While the character of the flux has little influence on the reaction, it has important relation to the yield and quality of the metal obtained. A silicious flux naturally occasions the introduction into the manganese of a certain proportion of silicon. If the flux be too fusible a quantity of the aluminum may rise to the surface and escape the reaction. A mixture of lime and fluorspar has given us the best results in crucible operations.

Theoretically, one part of aluminum should yield three parts of manganese; the best results we have obtained on the small scale, producing several pounds of manganese at one operation have given us two and eight-tenths parts or ninety-three per cent. of the theoretical yield, and our average yield has been about eighty-seven per cent. With aluminum at its present price we therefore estimate that the absolute cost of producing carbon-free manganese containing, Mn ninety-six to ninety-seven per cent., Fe and Si each one to two per cent., by our process, will be within thirty-five cents a pound, this estimate including all expenses.

On the large scale we purpose conducting the operation on a magnesite lined hearth, reducing gases being in slight excess. By this means we believe that the manganese will be retained in the state of lowest oxide until the temperature of reaction is reached, and that the prompt fusion of the flux at this stage will protect the manganese formed from contamination by carbon from the flame.

We may mention in conclusion that having experienced considerable difficulty in obtaining and preparing magnesite crucibles, we adopted the expedient of lining plumbago crucibles with a stiff paste of calcined magnesite. When properly prepared, these linings do not crack on drying,

and do not shrink from the plumbago walls. After thorough drying, the crucibles are ready for use, and we have found the linings very serviceable, not only for the preparation of manganese, but in other metallurgical work in which silicious or plumbago crucibles were from any cause objectionable.

SOME PRINCIPLES THAT MUST BE OBSERVED IN ORDER TO MAKE A GOOD CLOSED-CIRCUIT BATTERY, AND A NEW PORTABLE DRY CELL DESCRIBED IN WHICH THESE PRINCIPLES ARE APPLIED.

BY E. F. NORTHRUP.

[*A paper read before the Electrical Section, Dec. 28, 1892; Jan. 24, 1893.*]

The different types of primary batteries now upon the market are very numerous. Those acquainted with the subject know that all are more or less defective and that few, if any, give the efficiency that the theory of galvanism would seem to promise. Much excellent and exhaustive work has been done in determining the laws of electrolytic action and the general principles of chemical electricity, but fewer persons with the requisite chemical and mechanical knowledge have devoted themselves to the actual construction of cells which shall be free from practical defects and closely realize the theoretical possibilities.

The following general considerations may help to indicate the necessary limits to improvements in batteries and the paths in which to make an advance.

Prof. F. B. Crocker has shown, in a paper published in vol. v of the *Proceedings of the American Institute of Electrical Engineers*, the necessary cost of electric energy obtained by chemical means, and has reached the conclusion that primary batteries can never approach the dynamo in respect to economy or efficiency. There are, however, numerous cases, such as bell work, telephone, telegraph, medical and testing work where the cost of electric energy

is of a secondary consideration and where a thousand watts may be worth as many dollars.

If a cell is to give a constant current, or in short, be an efficient generator of electricity, there are certain cardinal principles which must be observed. Most of the literature upon batteries states how they *have been* made, not how they *should be* made, it being customary to describe the construction of special cells rather than the broad principles of application to all types. The following is an endeavor to briefly indicate these principles:

All substances may be divided into (1) non-conductors; (2) conductors which are not decomposed by the passage of an electric current; (3) electrolytes or conductors which are decomposed by the passage of a current. A circuit made up of substances of the second class can never maintain a current except by the application of a foreign force or source of electro-motive force. If it did, the result would be perpetual motion. This source of energy outside of the circuit may be in the form of heat that is applied to the junction of two dissimilar metals in the circuit, in which case there is thermo-electric current. If, now, a substance of the third class, an electrolyte, is introduced into a conducting circuit of the second class, and a current is made to pass through the entire circuit, the electrolyte is decomposed, according to a well-known law. But it is not necessarily true, on the other hand, that because the electrolyte of a circuit decomposes a current will flow. The energy of decomposition may take the form of heat at the seat of the chemical action and then there is no current. This would be the case if two similar pieces of zinc, which made up part of a conducting circuit, were dipped in a strong solution of hydrochloric acid. Rapid decomposition of the electrolyte would ensue, but no current would flow. The condition essential in order that the energy of decomposition may take the form of a galvanic current, is that the decomposition which results shall be due to a *stress* in the electrolyte brought about by an unequal attraction of the two electrodes for the different constituents, or ions, as they are called, of the electrolyte. In order that this

unequal attraction may be exerted, the electrodes must be at, what is called, a different potential from each other. This difference of potential may be brought about by the aid of an external source of electro-motive force, such being the case with the differently charged electrodes of a voltameter. Or, the two electrodes may tend inherently to maintain themselves at unlike potentials. Looked at from a chemical point of view, this inherent difference of potential possessed by the electrodes is the same thing as their unlike attraction or chemical affinity for the negative atoms or ions. The reason why different elements thus possess different potentials, or what is very probably the same thing, unlike degrees of chemical affinity, is not understood, but it is the fundamental fact which renders galvanic action possible. In short, the true source of the electric energy in a galvanic cell is to be found in the *unequal* chemical affinity which the two electrodes have for the atoms or ions of the electrolyte. Zinc and copper, for example, both attract chlorine, but zinc much more than copper, and hence negatively charged chlorine atoms will move from copper to zinc in an electrolyte of HCl. In the case of a $Zn/H_2SO_4/PbO_2$ couple, zinc has an affinity for SO_4, and PbO_2 has no affinity for that, but possesses a strong attraction for H_2, hence as each element pulls towards itself unlike ions, there is a strong stress in the electrolyte which means a correspondingly high electro-motive force.

The energy of the decomposition, when this is due only to the difference of potential of the electrodes, which produces the stress in the electrolyte, determines the force with which the current is urged forward, and a formula has been given by Lord Kelvin with which the electro-motive force of any combination can be calculated. (See Prof. F. B. Crocker's article, mentioned above.) This formula, however, only holds good in the case of a reversible element, viz: a cell in which all the energy of decomposition takes an electrical form, so that a reversal of the current will, theoretically, restore the cell. But under the ordinary conditions, as given above, an electrolyte will not continue to decompose, and the current at once ceases. The

reason for this is that the constituents into which it is decomposed, the ions, are deposited upon the surfaces of the two electrodes. These electrodes, if originally of a different potential from each other, are soon brought by this deposit of ions upon them to the same potential, for the ions themselves, being reckoned in the tension series, are always of opposite potential to the electrode upon which they are deposited. But if these ions, by any means chemical or mechanical, are removed as fast as they are deposited, electrical equilibrium cannot be established and the current will continue to flow.

This brings us to the three essential features of any galvanic arrangement which will furnish a continuous current: (1) A medium capable of decomposition, and which is called the electrolyte. (2) Two undecomposable conductors which make contact with this electrolyte and which are removed from each other more or less in potential, the farther the better. (3) Some source of energy, chemical or mechanical, which shall remove the ions as perfectly as possible and prevent electrical equilibrium from being established; in short, a depolarizer.

If the cell is to be efficient, each of these three parts must act efficiently. The electrodes must be removed from each other in potential as far as possible, the electrolyte must be easy to decompose, the depolarizer must be active, and all three parts must have good conductivity.

Theoretically, two depolarizers are required, one for the positive electrode to remove the negative ions, and one for the negative electrode to remove the positive ions. Practically, only one is required, for the positive electrode has such a strong affinity for the negative ions which form upon it that its own atoms unite with the negative ions, the electrode itself being thus consumed or burned, and this consumption is the continued source of energy at the positive electrode. But, unfortunately, a like action does not take place at the negative electrode, when such electrode is an element, for carbons and the metals capable of forming the negative electrode do not have a sufficiently strong chemical affinity for the positive ions to unite with them in a like

manner. There is one exception to this in the case of arsenic, when it is used as the negative electrode. For the positive hydrogen atoms will unite with metallic arsenic to form As_2H_4, and as the negative atoms at the same time unite with the positive electrode, the current will continue to flow though the cell employs elementary substances for its electrodes and has no depolarizer in the ordinary sense of the word. A couple, as for example $Zn / H_2SO_4 / As$, employs very cheap materials, but it gives only about seven-tenths of a volt and many other objections prevent this combination from being of much practical use. The solid elements, such as sulphur or iodine, which will unite with the positive ions, are non-conductors, hence it becomes necessary to introduce into the circuit about a negative electrode of good conductivity a strongly negative element, which will unite with the positive ions and remove them as fast as formed.

Now, whatever form of battery may be adopted, there are certain general principles applicable to each of these three essential parts of a cell, viz: the electrodes, the electrolyte and the substance which serves for the negative depolarizer, which must be taken account of in order to make the apparatus efficient.

The Electrodes.—It is difficult to conceive a case in which it would be preferable to have a given amount of energy in a large, rather than in a small space, hence, as electrical energy is the product of current and electro-motive force, it becomes desirable that the cell should have as high an electro-motive force as is consistent with other considerations. When all the elements are excluded, which are more costly than silver and those which are non-conductors of electricity, we have only the following list to choose from:

Potassium,	Tin,	Bismuth,
Sodium,	Lead,	Mercury,
Magnesium,	Iron,	Nickel,
Zinc,	Cobalt,	Platinum,
Cadmium,	Copper,	Arsenic,
Aluminum,	Antimony,	Carbon.

The Positive Electrode.—The first three of these elements, together with their zinc alloys, cannot be used in electrolytes which contain any water, as they almost universally do, because their affinity for oxygen is stronger than that of hydrogen and consequently the water is decomposed with a consumption of the electrode and with evolution of hydrogen gas. Cadmium, and the metals which follow it, give a lower electro-motive force than zinc and are not cheap enough as yet to make them more economical than zinc. Iron has been used, but it has disadvantages besides its low electro-motive force, such as the formation upon its surface of an insoluble and non-conducting film which runs up the resistance of the cell. Thus zinc, considering its cleanliness, cheapness and high potential, appears to be the best metal to employ for the positive electrode. Amalgamating it diminishes local action and slightly raises its electro-motive force. It may be alloyed with advantage only where fine adjustments of electro-motive force are sought, as might be the case in cells designed for standards of electro-motive force.

The Negative Electrode—Much greater opportunity is offered for improvements in the negative electrode, both in respect to material and form. Negative electrodes may be divided into (1) those which are depolarized by an element not chemically united with the electrode; (2) those in which the depolarizing element is chemically united with the electrode, and (3) those which depolarize themselves chemically, as in the single case of arsenic, or mechanically, as by the exposure of a large extent of surface.

If the first class is used, then the following considerations must determine its material; the lower its potential the better. But if the depolarizer that is used is reduced by the action of the current to a metal which is deposited upon the electrode, then the electrode must have exactly the same potential as the reduced metal. Otherwise wasteful local action may take place, for a couple will be formed between the reduced metal, which is at one potential, and the electrode, which is at another. For example, with copper oxide

for a depolarizer, copper and not carbon should be used for the negative electrode.*

When, on the other hand, the depolarizer is an element, or a compound which is reduced to an inert material, such as PbO_2 reduced to PbO or Pb_2O_3, carbon makes by far the best electrode. It is cheap, nearly as negative as platinum, and, as we shall see later, can be made to serve the purpose of a porous cup as well as electrode.

The second class of negative electrodes, viz: those in which the depolarizing element is chemically united with the electrode, as is the case in the chloride of silver cell, is better discussed under depolarizers. The third class can at the best only be of service in open-circuit cells and will not be considered here.

The form given to the electrode is often quite as important as its material, especially when carbon is used. Most of the solid compounds employed as depolarizers have a high resistance, and all the elements which will serve the purpose are by themselves non-conductors (arsenic excepted), hence, if the carbon electrode is embedded in such a depolarizer and exposes but a small surface, the cell will have a high internal resistance and much of the electrical energy will be unavailable, as it will spend itself in heat within the cell. This is the way cells are often constructed, viz: with an electrode surrounded with a depolarizer of low conductivity. Liquid depolarizers, excluding the liquid element bromine, are not open to this objection, and hence the high efficiency of the Bunsen element, the gravity cell and others of that class. The best form to give the carbon electrode, for overcoming the internal resistance which results from using depolarizers of low conductivity, will be more clearly understood after a discussion of the depolarizing elements.

The Electrolyte.—The qualities, physical and chemical, which place a substance in the third class and make it an electrolyte, are so numerous that they can only be briefly

* Since the above was written I have made experiments which show that salts of mercury and carbon can be used together without any appreciable local action taking place. E. F. N.

mentioned here. Those interested are referred to "Meyer's Modern Theory of Chemistry," 1888 edition, page 532.

In general, no substance is an electrolyte which does not contain one or more of the six elements, S, O, Fl, Cl, Br and I. No substance will act as an electrolyte unless its particles are mobile and hence crystalline salts and solids in order to act as such must be either fused or dissolved in a liquid. Glass, for example, when fused becomes a very good electrolyte. Though pure water, alcohol and ether are non-conductors, the first becomes a very good one when mixed with certain substances, and the last two also become conductors when some salts are dissolved in them.

All electrolytes decrease in resistance with increase in temperature, and this makes one of the tests of the class in which to place a substance. Generally speaking, a dilute solution has a lower resistance than a concentrated one. Acid and alkali electrolytes give, as a rule, higher electro-motive forces than salts, but they are open to the objection of being liable to consume the positive electrode, which means that some of the energy stored up in the cell is given out in local heat instead of electricity. As a rule salts are better adapted to hermetically sealed cells, and acids or alkalies to open cells. If a salt is used, it should usually be a salt of the metal employed for the positive electrode with an acid radical the same as the active depolarizing element, for after the cell has been in action such a salt is always formed, and if other salts are present there is a liability that double salts may be produced, which will increase the resistance of the cell, or at least make complicated what might otherwise be simple. Thus in a zinc carbon couple, with bromine for a depolarizer, zinc bromide would be better to use than magnesium chloride. This is not, however, an inflexible rule to follow, for special cases may require special salts. The relations of the different excitants and their degrees of concentration to the electro-motive force obtainable with different combinations of electrodes has been fully worked out by investigators, and the results of the same are well presented in Tommasi's "Traité des Piles Électrique," which work, by the way, is one of the best records of what has

already been done in the practical construction of galvanic batteries.

It may be observed here, that as water is almost always present in the electrolyte, its hydrogen is deposited upon the negative electrode and causes the polarization. This is *always* true where the excitant salt is an oxygen salt of an alkali or alkaline earth metal, and generally so with other salts. This is due to a secondary action which takes place. If, for example, a salt of a positive metal like sodium is employed, when the metal is separated from the acid radical it at once decomposes the water and frees its hydrogen, the metal itself forming a hydroxide with the remaining portion of the decomposed molecule of water, thus

$$Zn_x + 2\,NaCl + 2\,H_2O + C = Zn_{x-1} + ZnCl_2 + 2\,NaOH + H_2 + C,$$

or

$$Zn_x + 2\,KOH + 2\,H_2O + C = Zn_{x-1} + Zn\,(OH)_2 + 2\,KOH + H_2 + C.$$

In fused electrolytes, where no water is present, this action, of course, cannot take place.

A further discussion of electrolytes would be more interesting from a scientific than from a practical standpoint, for they have never given trouble in the actual construction of an efficient battery. The chief thing that has to be taken note of is that the excitant is not of a kind or concentration to dissolve any part of the cell and produce local action. This is the reason that KOH cannot be used with advantage in a silver chloride cell, though the electro-motive force is much greater than with NH_4Cl, which is usually employed.

The Depolarizer for the Negative Electrode.—As the negative electrode is polarized by the formation upon it of hydrogen, it can only be chemically depolarized by such substances as will unite with nascent hydrogen. Now, whatever compound is used, the depolarizing is actually done by one of these seven elements, As, S, O, Fl, Cl, Br or I, or one or more of these in combination. Theoretically, some other elements belonging to the group of non- or

semi-metals will unite with nascent H, but their affinities for H are weak and practically could never with advantage be used. Arsenic and sulphur also have weak affinities, giving under the most advantageous circumstances less than a volt and generally less than half a volt. Fluorine is far too powerful to be used, either free or in combination. So, practically, a battery always makes use of O, Cl, Br or I for its negative depolarizer, though these may often act in a combined state as in the case of the acid radical SO_4. As the depolarizing is actually done by one of these four elements or two of them in union, it is obvious that the other element or elements with which they may be combined are so much inert material which play no part in the production of the current, and usually only act to clog up the cell, increase its internal resistance and add to the total bulk occupied by the materials. Hence, the theoretically perfect cell would employ electrodes at opposite ends of the potential scale, and have the negative electrode depolarized with the most negative free element. The parts would be so adjusted that all would be finally consumed at the same time, and the cell go to pieces like Dr. Holmes' "One Hoss Shay." There are certain difficulties connected with the use of free elements as depolarizers, which have led to the adoption of their compounds instead. In the first place, any element or compound which will give up an element capable of uniting actively with hydrogen, and hence serve the purpose of a depolarizer, will also attack the positive electrode of the cell. Therefore, the depolarizer must be kept separated from the positive metal. The difficulties of doing this are increased when the depolarizer is a liquid or gas. Oxygen and chlorine being gases, and both of them also but slightly soluble in water, are thus difficult to employ. Bromine and iodine in an unmixed or uncombined state have the disadvantage of being non-conductors and must be used in some special way if the current is to find free passage between the electrodes. The former, moreover, is an exceedingly penetrating liquid, which will diffuse with great rapidity through any porous partition which will permit the passage of the ions. Iodine, though much easier

to handle, and though nearly insoluble in pure water, is soluble in iodides of the metals and has heretofore only been used for experimental purposes. But whether an element or a compound be used for the depolarizer, it must be kept separated from the positive electrode. (1) This may be done by making the depolarizer an insoluble compound which will not tend to diffuse through the electrolyte. (2) By using a heavy oily liquid in the bottom of a cell which has no tendency to mingle with water. (3) Imperfectly by using porous cups or the gravity principle.

It is obvious that only cases one and two are applicable to small sealed portable cells, for if the depolarizer has a tendency to diffuse, no porous partition or gelatinous paste which will permit the passage of the ions will permanently arrest the action of diffusion, and a small dry cell made with a depolarizer which has a tendency to mix with the electrolyte will surely and inevitably carry on a local action resulting, in time, in its destruction. To be sure, this process is a matter of *degree* and may be greatly delayed and possibly kept back long enough to make a cell constructed upon this principle that is not invaluable. I may say here, however, that I experimented with small cells having a soluble depolarizer, which I attempted to keep in place by means of porous partitions and gelatinous pastes and found it to be practically impossible to make one that would last, upon open circuit, above a few months.

In respect to efficiency, a liquid depolarizer is much better than a solid depolarizer, and a gas best of all, for with solid substances the exhausted particles cannot be replaced as in the case of liquids and gases. For this reason the compounds PbO_2, MnO_2 and others of similar qualities do not depolarize effectively, or if they do, at least cause a high resistance in the cell. There is an exception to this rule in the case of cells made on the principle of the silver chloride and copper oxide cells, in which the reduced metal is left in a spongy state which permits the hydrogen to be absorbed into its mass until it comes in contact with the still unreduced oxide or chloride.

Of the free elements bromine, while being one of the

cheapest, is a very powerful depolarizer, giving with the combination $Zn/MgCl_2/Br/C$, 1·9 volts. It is comparatively easy to handle, and when dissolved in CS_2 loses largely its fuming nature and if properly used does not lose its depolarizing properties. Some experiments made with this element showed that the carbon electrode could be made to serve the double purpose of electrode and porous cup. This was accomplished by taking a piece of an ordinary electric light carbon and boring a three-sixteenth inch hole down the centre for a distance of two inches. This hole was filled with grains of carbon, and free bromine was then poured into the hole. The hole was stopped with a carbon plug and connection made with a platinum wire. Such an electrode, ½ inch in diameter and 2 inches long, was placed in the centre of a five-ounce beaker containing a sheet of zinc for the positive electrode and with an excitant of KOH. This arrangement gave over two volts and three and one-fourth ampères as read upon a low resistance ampèremeter. Such a high efficiency was of short duration, as the bromine soon became exhausted, but the experiment goes to show that use may be made of non-conducting liquids for depolarizers when applied in this way. If porous cups could be dispensed with and the free elements O, Cl, Br or I in solution used in some such manner as the above, a very high efficiency might be attained.

I do not attempt to give details at this time about the construction of cells which make use of the free elements, but merely wish to point out the direction in which I believe increased efficiency in the production of galvanic electricity must be sought.

The difficulties in finding a suitable depolarizer for an hermetically sealed transportable cell are much greater than for an open battery which remains stationary. The sealed closed circuit cells now upon the market, which are good for anything, use a silver salt, which, under the most perfect conditions, will make a horse-power cost 119 times as much as it can be obtained for with free bromine, or five and one-half times as much as with free iodine. This observation is made, however, on the assumption that the silver used is

not recovered. As above stated, the depolarizer must be a solid, or at least of an oily nature, so that it will not diffuse through the electrolyte. If the salt of any metal is used which is reduced by the action of the hydrogen to the metal a potential of not over one and one-half volts can possibly be obtained (unless the rarer metals, such as osmium are made use of), and the cells that give that potential have some serious defects. If, on the other hand, an oxide like PbO_2 is used, which is not reduced to the metal, a higher electro-motive force is possible, but the resistance of such a cell is quite sure to be high. Moreover, the list of insoluble depolarizers which will give an electro-motive force of over a volt is not long. Among the free elements, oxygen and chlorine, being gases, cannot be used. Bromine and iodine, however, may be, and it is these elements that are employed in the new cells to be described.

Non-essential Parts of Cells.—Besides the three essential features of every battery, viz: electrodes, electrolyte and depolarizer, there are certain other parts often required that deserve a few words.

The case for a cell is usually made of glass, but often zinc, copper or carbon are employed, and serve for one of the electrodes of the cell. If this arrangement is adopted and several cells are used together, they must be insulated from one another, so that economy in space is not necessarily gained. This plan is usually adopted to obtain surface and so reduce the resistance of the cell.

In all so-called dry cells the electrolyte is used in the form of a semi-liquid paste. As this paste is usually employed, it merely serves the purpose of holding the contents of the cell in a more or less rigid condition, by which means the battery is made more readily transportable than it would be if it contained a liquid free to move about. But the paste in a hermetically sealed cell can be made to serve a much more important function. Where the product of the union of the hydrogen with the depolarizing element is an acid, this acid must be neutralized, in order to prevent its action upon the zinc and the consequent formation of a gas. This is best accomplished by the use of a paste which consists of some

basic material. All organic substances, like starch or the hydrate of silica, which are often used as pastes, are non-basic and will not serve the purpose of neutralizing an acid, and in a small cell are of little value. Any cell which uses as its depolarizer a salt with a haloid acid radical, should therefore make use of some such product as MgO or ZnO if gassing is to be prevented. The neutralizing action of the paste which takes place may be shown thus:

$$ZnO + 2\,HBr = H_2O + ZnBr_2$$

or

$$Mg(OH)_2 + 2\,HCl = MgCl_2 + 2H_2O.$$

The objection may be raised to this view of the function performed by a paste consisting of a basic salt, that the acids formed by the action of the cell are exactly neutralized by a corresponding amount of alkali supposed to be formed at the same time, and hence the basic salt in the paste is superfluous. If we examine the following equations, which are supposed to represent the normal action of a $Zn_1 / NH_4Cl_1 / AgCl$ cell, the above objection would appear to be valid, thus:

$$Zn_x + 2\,NH_4Cl + 2\,H_2O + 2\,AgCl =$$
$$Zn_{x-1} + ZnCl_2 + 2\,NH_4OH + 2\,HCl + Ag$$

and then

$$NH_4OH + HCl = NH_4Cl + H_2O$$

and so no acid remains to be neutralized. This normal action, however, does not in reality take place, especially when the cell is worked hard. It is probably very much more complicated and is a thing very difficult to investigate. Practical experiments were tried, using a basic paste on the assumption that acid is formed in the cell in excess of an alkali, and is the cause of the hydrogen gas which is certainly produced in considerable quantity and that this paste would thus prevent gassing by neutralizing the excess of acid. The assumption was evidently correct, as numerous trials made of such a paste was found to prevent the gassing not only in the silver chloride cell, but in several other types having depolarizers containing one or more members of the hydrogen group.

The same objection is open to a paste that applies to

solid depolarizers, viz: they do not allow diffusion of exciting liquids to take place as freely as it would in a liquid electrolyte. This objection, however, is proved by experiment to be much less than would be supposed. The resistance, moreover, caused by the use of a paste, if properly made, is insignificant.

[*To be continued.*]

ANNUAL REPORT OF THE BOARD OF MANAGERS OF THE FRANKLIN INSTITUTE.

(For 1892.)

The Board of Managers of the Franklin Institute of the State of Pennsylvania for the Promotion of the Mechanic Arts, respectfully presents the following report of the operations of the Institute for the year 1892:

MEMBERS.

Members at the close of 1891,	2,073	
Number of new members elected who have paid their dues,	98	
		2,171
Lost by death or resignation,	57	
Dropped for non-payment of dues,	81	
		138
Total membership at close of 1892		2,033

FINANCIAL STATEMENT.

Balance on hand January 1, 1892,		$349 67
Receipts:		
Contributions from members, annual,	$5,034 00	
Contributions from members, life,	350 00	
Certificates of stock, second class,	10 00	
Income from legacy of Geo. S. Pepper,	1,252 50	
Income from Bloomfield Moore fund,	672 39	
Income from memorial library fund,	60 00	
Interest on investments new building fund,	340 00	
Interest on B. H. Bartol fund,	60 00	
Interest on investment of Institute funds,	794 00	
Temporary loan,	4,350 00	
Cash from mortgage, belonging to B. H. Moore Fund,	10,000 00	
Cash from subscriptions to, and sales of, the *Journal*, fees for drawing school and other sources,	8,860 78	
		31,783 67
		$32,133 34

Payments:

Committee on library,	$1,088 06	
Committee on instruction,	2,255 08	
Curators,	2,017 55	
Salaries and wages,	4,618 00	
Insurances,	900 00	
Bloomfield Moore fund expenditures,	660 87	
Memorial library fund expenditures,	20 39	
Temporary loan,	2,350 00	
Interest on temporary loan,	83 34	
Investments, Bloomfield Moore fund,	10,000 00	
Other expenditures,	7,963 08	
		$31,956 37
Balance on hand December 31, 1892,		$176 97

LIBRARY.

The annual report of the Committee on Library exhibits the fact that the additions to the Institute's collection of books, pamphlets, etc., during the past year have been below the average of the previous three or four years, although a fair increase is shown. This falling off is due principally to the fact that the committee's appropriation for the year 1892, was curtailed by one-third, this restricting them materially in the matter of purchases.

The policy in respect of the use of the Library for consultation by the public that was instituted in 1888, has been pursued, and while it has been found at times to throw considerable extra work upon the limited force of employés, it is probably as satisfactory a plan as could be devised.

The details of the year's work in the Library appear in the committee's annual report, to which the Board refers.

THE JOURNAL.

The *Journal* has fully maintained its excellent reputation. The Committee on Publications has given to its conduct and management the same careful and intelligent consideration as in previous years, and have continued to keep it on a self-supporting basis.

With the approval of the Board, the committee has been authorized to make the experiment of sending the *Journal* to all members of the Institute, beginning with the January impression of the current year and without present increase of annual dues.

It is confidently anticipated by this step that the interest of the membership generally in the work of the Institute will be increased.

Further information respecting this important departure from long-time usage appears in the committee's report.

To insure that the Institute shall not be at any pecuniary loss in carrying this project into execution, the committee with the co-operation of a number of the members who are convinced of the wisdom of the measure in pro-

moting the welfare of the Institute, has obtained subscriptions to a guaranty fund which it is believed will be adequate for the purpose until such time as the growth of the business of the *Journal* shall be sufficient to meet the increased cost of publishing its enlarged edition.

COMMITTEE ON SCIENCE AND THE ARTS.

The annual report of the Committee on Science and the Arts shows that the committee has fully maintained its activity. The great interest displayed by the members of this committee in conducting the frequently exacting and laborious duties incident to the investigation of inventions submitted to them by applicants for reports or by the Institute, is most praiseworthy, and the Board is satisfied that the interests of the Institute are well served by this committee. The annual report of the committee will exhibit the details of the work for the year.

LECTURES.

The arrangement of the lecture course for the season of 1892–93 has been made upon the same lines as those of the preceding few years. The Committee on Instruction, with the co-operation of the professors, succeeded in maintaining the high character of these lectures by securing the services of many men of eminence, and the publication of many of these lectures in the *Journal* has added greatly to its interest, and at the same time to the reputation of the Institute.

DRAWING SCHOOL.

The number of pupils in the Drawing School is shown by the accompanying statement:

At spring term of 1892, ...	199
At the winter term of 1892, ...	200
	399

being a decrease of 106 as compared with attendance of 1891.

The chief reason for this falling off in attendance is doubtless to be sought in the growth of facilities for this species of instruction in other local institutions.

SECTIONS.

The continued activity of the Chemical and Electrical Sections is gratifying. The Electrical Section especially shows a highly gratifying growth both in membership and in the number and interest of its papers and discussions.

The influence of these two bodies in encouraging and promoting original research is of the highest importance, and the Board refers to their work with special satisfaction. The annual reports of the Sections will exhibit the details of their operation during the year.

STATE WEATHER SERVICE.

The Committee on Meteorology with the coöperation of the Assistant assigned to the work by the Weather Bureau at Washington, has succeeded in maintaining substantially unimpaired the organization of the State Weather Service, thanks to the interest and zeal manifested in the work by the voluntary observers in the various counties of the State.

Thus, the continuous record of the meteorology of the State has been kept unimpaired.

Through the courtesy of the Honorable Secretary of Internal Affairs, also, the committee has succeeded in having the monthly summaries of the reports of the observers and certain important special reports printed and has been enabled to include these in the *Journal* without cost to the Institute.

It will be of interest to state that the World's Fair Commissioners of the State were sufficiently impressed with the value of the service to grant an appropriation of $1,700 to provide for an adequate exhibit of its work, which will embrace illustrations of its methods, instruments, charts and other publications.

It is hoped that at the present session of the Legislature, the grant of an appropriation adequate to continue the work on a scale commensurate with its importance will be made. It is certainly earnestly to be hoped that this service, so importantly related to the commercial and agricultural interests of the State and so excellently organized for useful work, will be maintained unimpaired.

GENERAL REMARKS.

It is much to be regretted that a better exhibit cannot be made as to the financial condition of the Institute. The receipts for membership are even less than those for last year, which had decreased from those of the year previous. It is hoped, however, that the radical departure which has recently been made in furnishing the *Journal* to members, free of cost, thereby giving them not only a valuable return as an additional privilege for membership, but also keeping them thoroughly alive to the doings of the Institute, will tend to very much increase the number of members, both resident and non-resident.

For the latter class this privilege is especially valuable, as it gives a large return for a small fee, and furnishes a substantial inducement for such membership, notwithstanding the deprivation of the local use of the Institute building.

So much has been said in previous reports as to the extreme desirability of a fire-proof building with increased accommodations, that little can be added, except to keep the subject before the Institute and its friends.

It is hoped that some feasible way may be opened towards the accomplishment of what we know must be in the hearts of all who cherish and appreciate the Franklin Institute and its work.

By order of the Board.

JOSEPH M. WILSON, *President.*

ANNUAL REPORT OF THE COMMITTEE ON LIBRARY.

(For the year 1892.)

To the President and Members of the Institute:

GENTLEMEN:—The Committee on Library makes the following report, embodying the important facts concerning the operations of the library during the year 1892.

During the year, the following additions were made to the Library:

Bound volumes,	1,242	
Unbound volumes,	563	
Pamphlets,	1,174	
Miscellaneous publications,	528	
Total additions,		3,507
Being a decrease from the previous year of,		1,055
Total number of volumes in library, December 31, 1891,	37,183	
Additions bound and unbound volumes, during 1892,	1,805	
Total number of volumes at close of 1892, in library,		38,988

Pamphlets.—

Total number in library December 31, 1891,	22,183	
Additions during 1892,	1,174	
Total number at close of 1892,		24,357

The library also contained at the close of 1892, miscellaneous publications as follows:

Maps and charts,	2,476
Drawings, designs, etc.,	604
Photographs and lithographs,	1,150
Newspaper clippings,	189
Manuscripts,	21
Total,	4,440

Duplicates.—The number of duplicates in the library at the close of 1892, numbered:

Bound and unbound volumes,	1,576
Pamphlets,	4,078
Periodicals (numbers),	3,051

Moore Fund.—During the year 1892, 190 volumes and eight unbound volumes were purchased from the income of the Moore Fund, and six volumes were bound.

Gifts.—The Library received by gift:

Bound and unbound volumes,	1,285
Pamphlets,	1,137
Miscellaneous publications,	626

Exchanges.—The number of journals and societies on the exchange list at the close of 1892 was 405.

Public Use of the Library.—During the year 1892, the Library was used by 783 non-members, who consulted 2,457 volumes of patents and 997 volumes and pamphlets from other departments of the library.

Use of the Library by Members.—The Library records show that 2,149 volumes were withdrawn for home use by 257 members. The number of volumes consulted in the library, not withdrawn for use, considerably exceeded this number.

A comparison of these figures with the records of previous years show that the additions to the library and the use of the library by members and others are about up to the average. The decrease in the number of additions, as compared with the year 1891, is due chiefly to the fact that the appropriation at the committee's disposal was less by the sum of $500 than that available for the preceding year.

Respectfully submitted,

W. P. TATHAM,

Chairman of Committee on Library.

ANNUAL REPORT OF THE CHEMICAL SECTION OF THE FRANKLIN INSTITUTE.

(For the Year 1892.)

JANUARY 1, 1893.

Mr. Joseph M. Wilson, President of the Franklin Institute:

SIR:—I have the honor to submit the following report of the proceedings of the Chemical Section for the year 1892:

Although no great advances over the results of the past few years have been made, the Section is in its usual prosperous condition, and as shown by the demand for the printed copies of its proceedings in other cities, as well as in Philadelphia, its work appears to be appreciated.

The officers for the past year have been as follows:

President,	DR. WM. H. WAHL.
Vice-Presidents,	DR. E. F. SMITH, DR. WM. H. GREENE.
Secretary,	DR. WM. C. DAY.
Treasurer,	DR. H. W. JAYNE.
Conservator,	DR. WM. H. WAHL.

Stated meetings have been held as required by the by-laws, on the third Tuesday of each month, excepting July and August.

Membership.—The number of members on the treasurer's books at the beginning of the year was seventy-nine; since that time three new members have been elected, four have resigned, one has died and one was dropped for non-payment of dues, making the present membership seventy-seven.

Finances.—The recently submitted report of the treasurer shows cash on hand at the beginning of the year $131.85, received during the year, $136; expenditures amounted to $193.79, thus leaving on hand a balance of $74.16.

The following is a list of the papers which have been read before the Section at its ten regular meetings.

"Analysis of Eggio," by Mr. Charles S. Boyer.

"A New Form of Gas-measuring Apparatus," by Mr. H. Pemberton, Jr.

"A Rapid Method for the Determination of Carbonic Acid Gas," by Mr. H. Pemberton, Jr.

"The Electrolytic Deposition of Aluminum," by Dr. Wm. H. Wahl.

"The Composition of the Explosive Copper and Silver Compounds of Acetylene," by Dr. H. Keiser.

"Notes on Iron in Bone-black," by Dr. Bruno Terne.

"Derivatives of Lapachic Acid," by Dr. S. C. Hooker.

"Chestnut Bark Tannin," by Prof. Henry Trimble.

"The Influence of Bottles upon Wines," by Mr. Charles E. Ronaldson.

"An Improved Method of Determining Small Percentages of Gold and Silver in Base Metal," by Mr. M. Cabell Whitehead.

"Armor-plate Tests at Indian Head Proving Ground," by Mr. F. Lynwood Garrison.

"On the Composition of the Liquid Ammonia of the Trade and How to Manufacture Liquid Ammonia of 99·995 Per Cent.," by Dr. Hans von Strombeck.

"Account of the Meeting of the Association of Agricultural Chemists at Washington," by Dr. Bruno Terne.

"The Washing of a Southern Coal: Comparison of Laboratory Results with those of Actual Washing Test," by Mr. Geo. W. Whyte.

"A Lilac Color from Extract of Chestnut," by Mr. T. C. Palmer.

"Deposits of Native Soda near Laramie, Wyoming," by Mr. H. Pemberton, Jr., and Mr. Geo. P. Tucker.

"Observations on Ferro-tungsten," by Dr. Wm. H. Wahl.

"Dibrom β-lapachone: its Preparation and Properties," by Dr. S. C. Hooker and Mr. A. D. Gray.

Approved at the stated meeting of the Section, December 17, 1892.

Respectfully submitted,

WM. C. DAY, *Secretary.*

REPORT OF THE ELECTRICAL SECTION OF THE FRANKLIN INSTITUTE FOR THE YEAR 1892.

To the President and Members of the Franklin Institute:

The Secretary of the Electrical Section begs leave to present the following report of the Section's proceedings for 1892.

Officers.—The business of the Section has been carefully and successfully conducted by the following officers:

President,	PROF. EDWIN J. HOUSTON.
Vice-Presidents,	MR. C. W. PIKE,
	MR. CARL HERING.
Secretary and Treasurer,	PROF. L. F. RONDINELLA.
Conservator,	DR. WM. H. WAHL.

Membership.—The Section now numbers fifty-one active members and eighteen associates, or a total of sixty-nine members. This is a slight increase over that at last report, fourteen names having been added to, and thirteen dropped from the roll during the year.

Finance.—The following is a summary of the Treasurer's report:

Cash in hand, December 30, 1891,	$15 68
Received from initiation fees, dues, etc.,	97 12
	$112 80
Paid for printing, clerical work, etc.,	103 93
Balance on hand, January 1, 1893,	$8 87

Meetings.—One special and ten regular meetings have been held during the year, at which there has been an average attendance of twenty-six. At the regular meeting of May, the Section's by-laws were amended by changing the time for regular meetings from the first to the fourth Tuesday of each month, excepting July and August.

Papers.—The following is a list of the papers that have been presented at the meetings of the Section, those indicated by an (*) having been printed in full in the *Journal of the Franklin Institute*, and in vol. ii of the Section's *Proceedings:*

"Recording Volt- and Ammeters." By H. S. Hering.

* "Electro-Magnetic Machinery." By Wm. S. Aldrich.

* "An Early Conception of the Magnetic Field." By Edwin J. Houston.

"Notes on the Power Transmission Plant at Niagara." "The Frankfort Electrical Exhibition." "Burton's Process of Electric Forging." By Carl Hering.

* "On the Variable Action of Two-coil Solenoids." By Wm. S. Aldrich.

* "The Constant Shunt Method for the Measurement of Continuous Currents." By C. W. Pike.

* "Cerebral Radiation." By Edwin J. Houston.

"The Oerlikon Works' Proposal for the Niagara Transmission Plant." By Carl Hering.

* "Dynamo and Motor Calculations." By C. H. Bedell.

"Experiments with High Potential Alternating Currents." (*Letter.*) By Elihu Thomson.

* "On Polyphased Currents." By P. Winand.

* "Ampère-centimetre: A Measure of Electro-magnetism." By Carl Hering.

"The Magnetic Influence of So-called Non-magnetic Substances." By E. G. Willyoung.

* "A Graphic Representation of the Magnetic Field." By Edwin J. Houston.

* "The Physiological Effects of Alternating Currents of High Frequency." By Edwin J. Houston.

* "Magnetic Disturbances on Weston Measuring Instruments." By C. W. Pike.

"A Home-made Thomson Reflecting Electrometer." By D. A. Partridge.

* "On Polyphased Currents." (Second part.) By P. Winand.

* "Additional Notes on the Graphic Representation of the Magnetic Field." By Edwin J. Houston.

"The Plant and Process for Aluminum Plating the Ornamental Iron Work for the City Hall." By Wm. H. Wahl.

* "Some Curiosities in Early Electro-therapeutics." By Edwin J. Houston.

* "A New Ballistic Galvanometer." By E. G. Willyoung.

* "On the Measurement of Energy in the Three-phase System." By P. Winand.

* "Some New Apparatus for the Most Exact Comparison and Adjustment of Resistance Standards and the Determination of Temperature Coëfficients." By E. G. Willyoung.

* "Errors in the Determination of Areas from Measured Diameters." By O. T. Louis.

* "Recent Improvements in the d'Arsonval Galvanometer." By Nelson H. Genung.

"Some Principles that must be Observed in the Construction of a Good Closed Circuit Battery, and some New Portable Dry Cells in which they are Applied." By Edwin F. Northrup.

In addition to this, many interesting queries from the *Question-Box* have been discussed, and views and experience on practical subjects have been exchanged.

Outlook.—The recent slight increase in the Section's dues will considerably improve its financial resources, and systematic efforts are now being arranged by which the new committees will probably be able to increase the number of new members and arrange more attractive programmes for the meetings of 1893. The outlook, therefore, at the end of this second year of the Section's existence is very encouraging.

Respectfully submitted,

L. F. RONDINELLA,

Secretary and Treasurer.

Franklin Institute.

[*Proceedings of the stated meeting, held Wednesday, Feb. 15, 1893.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, February 15, 1893.

MR. JOS. M. WILSON, President, in the chair.

Present, 116 members and eighteen visitors.

Additions to membership since last report, seven.

The resignations from the Committee of Science and the Arts of Messrs. Philip H. Fowler, John Hall, Lewis M. Haupt and Theo. C. Search were reported.

The vacancies were filled by the election of Mr. C. P. Schultz, in place of Mr. Fowler; Mr. Walter Balliet, in place of Mr. Hall; Mr. E. G. Willyoung in place of Prof. Haupt, and Mr. A. P. Winand, in place of Mr. Search.

Mr. James M. Price read a paper descriptive of his improvements in rail-joints, illustrating the same by the exhibition of a series of specimen joints and with the aid of lantern slides.

Prof. Angelo Heilprin gave a popular account of experiences of Arctic travel, with special reference to the recent expedition for the relief of Lieut. Peary, of which he was the commander. His remarks were illustrated with a series of interesting views shown with the lantern.

The Secretary, in his monthly report, made reference to the alleged anticipation of Mr. Edison in the invention of the incandescent electric lamp, by Henry Goebel, and offered some comments on the evidence presented to sustain the claim of the latter to be the prior inventor.

Adjourned.

WM. H. WAHL, *Secretary.*

BULLETIN FOR THE MONTH OF MARCH, 1893.

TO MEMBERS OF THE INSTITUTE:

[redacted]

Mr. JOHN M. HARTMAN will exhibit a series of interesting views of Ancient Egyptian Architecture, with appropriate comments thereon.

WM. H. WAHL, *Secretary.*

SCHEDULE OF MEETINGS.

Committee on Science and the Arts,	Wednesday, March 1, 8 P. M.
Committee on Library,	Monday, March 6, 4 P. M.
Board of Managers,	Wednesday, March 8, 8 P. M.
Chemical Section,	Tuesday, March 21, 8 P. M.
Committee on Meetings,	Wednesday, March 22, 5 P. M.
Electrical Section,	Tuesday, March 28, 8 P. M.

☞ MEMBERS are requested to present to the library copies of books, magazines and pamphlets (especially the latter), which they do not wish to preserve. A card addressed to the Librarian, notifying him when and where to send for such gifts, will receive prompt attention.

Franklin Institute.

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Adjourned.

WM. H. WAHL, *Secretary*.

BULLETIN FOR THE MONTH OF MARCH, 1893.

TO MEMBERS OF THE INSTITUTE:

The Stated Meeting will be held on

WEDNESDAY, MARCH 15, 1893, at 8 o'clock, P. M.

The following program has been approved by the Committee on Meetings:

Mr. JAMES M. PRICE will read a paper on the "Price Metallic Ties," with suitable illustrations.

Mr. JOHN M. HARTMAN will exhibit a series of interesting views of Ancient Egyptian Architecture, with appropriate comments thereon.

WM. H. WAHL, *Secretary.*

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